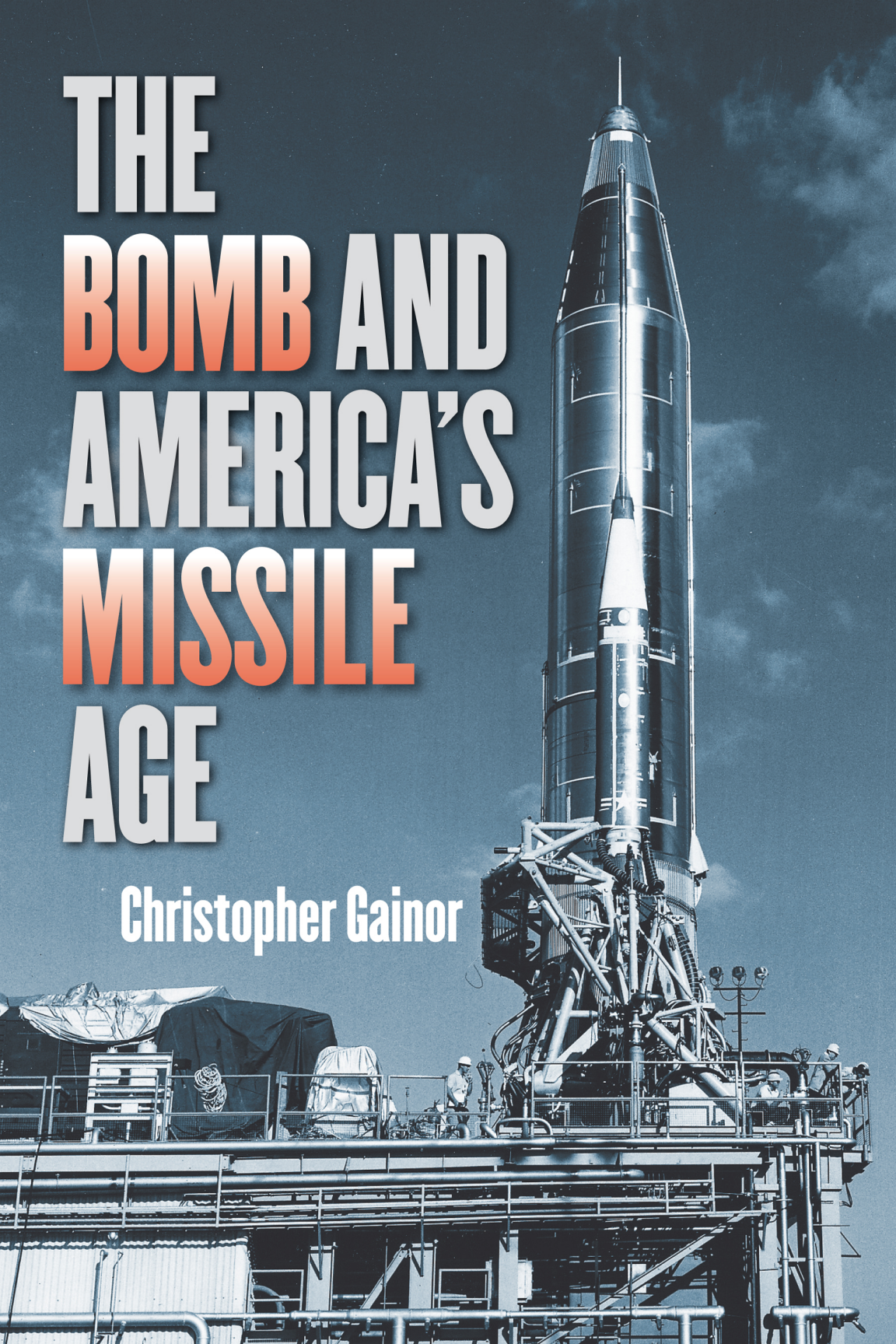
THE BOMB AND AMERICA'S MISSILE AGE

Christopher Gainor



VISIT…

The Bomb and America's Missile Age

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The Bomb and America's Missile Age

Christopher Gainor

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In Memory of
Timothy David Gainor,
1959–2008

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Preface

The story of how the United States came to build Atlas and other first-generation intercontinental ballistic missiles (ICBMs) begins in earnest in World War II and follows several strands over nine years. To understand how the story of Atlas came to be distorted, this work also carries the story to the early 1960s to recount how the early days of the American and Soviet space programs affected perceptions of the creation of the first ICBMs.

Chapter 1 describes the guided missiles that were created before and during World War II, including the German V-1 and V-2 missiles, and rocket programs in the Soviet Union and the United States before and during the war. The chapter ends with the creation of the first nuclear weapons, and the first suggestions in the United States that they be married with missiles.

To understand the air force's treatment of missiles in the years after the war, one must understand the changes it underwent during that time. Chapter 2 discusses the challenges facing the air force, and the political and technological issues surrounding nuclear weapons in the late 1940s.

Chapter 3 turns to the matter of missiles, and how the branches of the US military viewed them. Immediately after the war, scientists, engineers, and military leaders saw potential in several technologies, including jet engines, rockets, and nuclear propulsion, and the contest between the services for control of missiles was on even before the end of World War II.

Rockets were just one type of missile, and both the United States and the Soviet Union moved slowly to develop them in the years following World War II. Chapter 4 tells how the US Air Force started and then ended a program called MX-774 while the Soviets built a rocket replicating the German V-2 rocket.

Chapter 5 profiles Vannevar Bush, who headed America's military research and development programs in World War II and the early postwar years. Bush questioned the need for long-range rocket missiles while exercising strong influence over their development.

The year 1950 saw important decisions that ultimately led to the first US ICBM, including President Truman's decision to develop thermonuclear weapons. Chapter 6's discussion of that year shows that US policymakers were still focused on missiles designed to defend against Soviet bomber aircraft and missiles.

As the Korean War and a massive increase in financial support for the US military began in 1950, expert opinion in the United States started to shift in favor of rocket missiles, and, as outlined in chapter 7, the Atlas missile program began on a modest scale. American policymakers remained frustrated through this time over the lack of information about Soviet missile programs.

Chapter 8 tells the story of how American and Soviet authorities approved programs to develop their first ICBMs, the Atlas and the R-7. Although both superpowers had undergone changes in 1953, the development of thermonuclear weapons was the crucial factor in the decisions in both countries.

Once the two superpowers decided in 1954 to build ICBMs, both came face-to-face with their limitations as they built and deployed them, as outlined in chapter 9. The first ICBMs also had second careers as space launch vehicles, as discussed in chapter 10. Both chapters discuss the implications and the myths relating to the creation of the first ICBMs.

This study also includes an historiographical essay on the history of Atlas that focuses on earlier works whose arguments were based on suppositions from the early days of missile deployments and the space race between the United States and the Soviet Union.

I have always been interested in the history of space exploration, and like many people, my interest was focused on the space race in the 1950s and 1960s that culminated in the first human flights to the moon. Little had been written on the years between the end of World War II and the preparations that began in the mid-1950s for the first satellite launches. I had written about the US human space program of the 1960s and completed a master's degree in space studies at the University of North Dakota when Colin Burgess, who was editing a series for the University of Nebraska Press on the history of space exploration, commissioned me to write a book covering the steps leading up to the first human flights into space. My work on *To a Distant Day: The Rocket Pioneers* constituted my introduction to history of space exploration during the postwar years and to many of the issues that are covered in this book.

Even before *To a Distant Day* was published, I began PhD studies in history at the University of Alberta, and as I cast around for a dissertation topic, Roger Launius, a former NASA chief historian then at the National Air and Space Museum (NASM) of the Smithsonian Institution in Washington, DC, suggested that the time had come for a fresh look at what led to America's first ICBMs, which related to the history of space exploration because ICBMs also played major roles in the early days of both the American and Soviet space programs. That suggestion led to my PhD dissertation, which ultimately became this book.

Many people have helped me make this book possible. My faculty advisor at the University of Alberta, Robert W. Smith, provided invaluable help through the dissertation process, and his guidance on this book has continued to its completion. Dr. Smith showed great wisdom and patience in keeping me focused on the essential points, and his critical attention has vastly improved this book. Michael Neufeld, also of the NASM, provided a great deal of helpful criticism as a member of my dissertation committee and later for this book.

At the University of Alberta, I was also assisted by Susan Smith and David Marples. My work on this book was informed by Stephen B. Johnson, who introduced me to the topic of military missile and space programs while I was his student at the University of North Dakota. While working on this book, I published a related paper in *Technology and Culture*, whose editor Suzanne Moon and anonymous reviewers were most helpful in sharpening the paper and my thinking. I also thank Alexander C. T. Geppert, Daniel Brandau, and Tilmann Siebeneichner of the Emmy Noether Research Group, whose invitation to speak at the Embattled Heavens Conference at the Freie Universität Berlin in 2014 provided me with a great opportunity to further explore this topic.

At Johns Hopkins University Press, Elizabeth Sherburn Demers shepherded this book through the review process. I also thank William Krause, Matthew McAdam, and Lauren Straley at JHUP, copyeditor Ashleigh McKown, and especially the anonymous reviewers of the manuscript for this book, whose critical attention vastly improved it.

In addition, I'd like to thank the many archivists and librarians who assisted me while they went about their vital work. I gathered much of the documentary evidence for this book at the National Archives in College Park, Maryland; the Harry S. Truman Presidential Library in Independence, Missouri; the Dwight D. Eisenhower Presidential Library in Abilene, Kansas; and the US Air Force Historical Research Agency at Maxwell Air Force Base in Alabama.

NASM provided me with primary source material, as did the NASA History Office in Washington, where Steven J. Dick, John Hargenrader, Stephen Garber, and Jane Odom were always helpful. I made extensive use of the resources of the Library of Congress, the University of Alberta Rutherford and Cameron Libraries, the University of Victoria McPherson Library, the University of Washington Suzzallo and Allen Libraries, the University of British Columbia Library, the Greater Victoria Public Library, and the Vancouver Public Library. My friend Joel Powell, a font of information on the Atlas launch vehicle and on Cape Canaveral, helped with the illustrations.

Many friends extended a helping hand, including Steve Pacholuk, Ken Harman, Barry Shanko, Sue Birge, Steve Shallhorn, Forrest McCluer, Martha Starr, Mary O'Donoghue, Rolf Maurer, and Tom Hawthorn.

Among the books I have written so far, none has been more dependent than this one on support from my family. My wife, Audrey McClellan, helped me in more ways than I can count, and I am also grateful to members of her family, including Denise Thomson, Richard Bobier, and their daughter Solomia; Sandra McClellan; Kirby O'Connor; and Audrey's parents, Norman and Kathy McClellan. Every member of my own family also helped out, including my parents, Don and Toni Gainor, my sister Mary Gainor, and my brother Mark Gainor. I greatly regret that I won't be able to share this book with my dear brother Tim Gainor, who passed away while I was researching this topic, and to whom this book is affectionately dedicated.

Introduction

The defining weapon system of the Cold War was the intercontinental ballistic missile (ICBM) topped with nuclear warheads. In the early years of this long struggle between the Soviet Union and the United States, the bomber aircraft carrying nuclear bombs was the primary weapon system, and as time went on, submarine-launched ballistic missiles gained an important place in nuclear arsenals. But from the time the United States and the Soviet Union began activating them in large numbers at the beginning of the 1960s, nuclear-armed ICBMs were the primary weapons in the standoff between the two superpowers. ICBMs built by both the United States and the Soviet Union were also quickly put to use launching artificial satellites around the earth, space probes to the moon and planets, and the first humans into orbit. The race between the two adversaries to build ICBMs therefore powered the space race of the 1950s and 1960s. Today we are still living with the political, technological, and scientific effects of that Cold War competition.

ICBMs were designed first and foremost to deliver nuclear weapons to distant targets in enemy territory. They offered high-speed delivery of these weapons—less than half an hour to targets thousands of miles away—and even today, more than half a century after their introduction, they are almost impossible to intercept once in flight. The ICBM represented the marriage of two technologies that were advanced during World War II: nuclear weapons and large long-range rockets. The story of the nuclear bombs these missiles were designed to carry has won far more attention from writers and historians than has the story of the missiles. One reason is the unprecedented destructive power of nuclear weapons, and another is that this power was used to great effect and great controversy when nuclear bombs were dropped from bomber aircraft on Hiroshima and Nagasaki in 1945. These bombs were created by well-known scientists, many of whom came to disagree over how they should be used. And, so far, nuclear-armed missiles have never been used in anger. ICBM and nuclear weapons programs have always operated under a cloak of secrecy, which meant that they

were not written about as much as higher-profile launch vehicles developed purely for space exploration.

Atlas, America's first ICBM, was designed and built by the US Air Force (USAF), which also built Titan ICBMs and the shorter-range Thor ballistic missiles at almost the same time. The first generation of ICBMs has a double identity that has caused a great deal of confusion among historians and others who have written about them. These early ICBMs also made superb space launch vehicles, and the two roles have often been confused in public discourse, starting with the idea that a rocket capable of launching satellites was automatically well suited to deliver nuclear weapons. For much of the four decades from the time of their creation to the end of the twentieth century, most American satellites were launched atop derivatives of Atlas, the Titan II ICBM, or the Delta launch vehicle, which grew out of the Thor missile. The Soviet Union's first ICBM, the R-7, launched most early Soviet satellites and space probes, and uprated versions of the R-7 are still in use today, making it the workhorse of the Soviet and now the Russian space launch fleet.

The R-7 lies at the heart of the story of the Soviet space program. Describing the place of Atlas in the history of America's space efforts is not so simple, and thus its roots have not been fully explored or explained. When the US government launched its first artificial satellites, it used purpose-built satellite launchers from the US Navy and the US Army. Focusing on its mission to create an ICBM as quickly as possible, the USAF deliberately avoided making Atlas available as a space launch vehicle until it had proven itself for its primary mission.[1]

Both the United States and the Soviet Union began testing their first ICBMs in the spring of 1957. The first reported successful launch of an ICBM was the third test launch of the Soviet R-7 on August 21, 1957. Six weeks later, on October 4, the same rocket was used to launch Sputnik, the first artificial satellite of the earth, creating a worldwide media sensation. In November, an R-7 carried a dog into orbit, creating another media sensation. The Soviet Union went on to use the R-7 to launch the first object into solar orbit, the first spacecraft to reach the moon, and the first spacecraft to carry a human into orbit, along with other space "firsts." The identity of the people responsible for the Soviet rockets and spacecraft remained secret for years, and the real story of the Soviet missile and space programs didn't fully emerge until after the fall of the Soviet Union in 1991.

When the United States launched its first satellites in 1958, they flew on rockets that were far less powerful than ICBMs. Explorer 1, the first American satellite, was launched by the US Army's team of rocket engineers after scientists and engineers tied to the US Navy fell behind in their effort to launch a satellite. Successful test flights of the Atlas ICBM were obscured behind early failures and the successes of the Soviet R-7 as a space launch vehicle. Finally, in December 1958, when Atlas had been proven for its military purposes, the air force used it for the first time to launch a payload into orbit.

In the wake of Sputnik, Democrats charged that Republican president Dwight D. Eisenhower had allowed America to fall behind its Soviet adversary. The American political crisis that followed Sputnik has long shaped historical descriptions of the Cold War competition between the United States and the Soviet Union over missiles and space exploration. Many Americans believed that the early Soviet successes in space, coupled with America's slower start, meant that the Soviets had a clear lead in the field of space technology. They also believed that the Soviet Union had become the first country to have an operational ICBM, leaving America in the unaccustomed position of being vulnerable to attack.

Although Atlas suffered through a series of well-publicized problems in early test flights in 1957 and 1958, Soviet secrecy prevented outsiders from knowing that the R-7 also had troubles of its own in tests of its capabilities as a delivery system for nuclear weapons. The widespread American belief in Soviet missile superiority remained unchallenged through 1960, when Democrats claimed that the Eisenhower administration had allowed a "missile gap" to develop between the Soviet Union and the United States. By then, evidence obtained by U-2 aircraft overflights of the Soviet Union and, starting that summer, by CORONA reconnaissance satellites showed that the missile gap vastly favored the United States. Eisenhower remained silent to protect his intelligence sources, even as his vice president, Republican presidential candidate Richard Nixon, lost narrowly to Democrat John F. Kennedy in the election that November. High-ranking officials in the newly installed Kennedy administration admitted early in 1961 that the missile gap was a myth, and that fall, they also proclaimed the clear American superiority in nuclear-armed ICBMs and bombers over the Soviet Union.[2]

Soon after Kennedy took office, the Soviets launched the first human into space. Discomfited by Yuri Gagarin's spaceflight and by America's failed invasion

of Cuba at the Bay of Pigs a few days later, Kennedy responded by challenging American government, academia, and industry to land astronauts on the moon before the end of the 1960s. Kennedy and his successor, Lyndon B. Johnson, won the support of Congress for the moon-landing goal, and the United States overtook the Soviet Union in the space race and landed the first humans on the moon in 1969.

Despite the importance of ICBMs to the space efforts of both countries, and despite their place in the nuclear standoff that marked the Cold War, the origins of these missiles as delivery systems for nuclear weapons have often been glossed over or ignored in historical accounts. In the case of early US missile and space exploration programs, histories were often built around Wernher von Braun, the engineer and manager who directed Germany's V-2 rocket program in World War II, then headed a team of German rocket engineers who worked for the US Army from 1945 to 1960, and then joined the National Aeronautics and Space Administration (NASA) in the 1960s. Despite his work for America's enemy in World War II, von Braun emerged as a popular promoter of rockets and space exploration in 1950s and 1960s America. His army team built a missile that was used as the initial stage for America's first satellite and then was used to lob two American astronauts on suborbital flights in 1961. Von Braun and his group spearheaded the creation of NASA's Saturn rockets that took American Apollo astronauts to the moon. As he increased his profile as a leader of America's space efforts, von Braun also worked with his friends and supporters to write influential early histories of rockets and space exploration that fostered the idea that space exploration was inspired by space pioneers who in turn inspired space enthusiasts in Germany, including von Braun and his team, and in America and the Soviet Union. Today, historians such as Michael J. Neufeld, Howard E. McCurdy, and Roger D. Launius are reassessing von Braun's place in the history of rocketry and space exploration, questioning many claims made by his supporters about the centrality of his role in 1950s US space programs.[3] This book seeks to free Atlas and other early US ICBMs from the shadow of von Braun's oversized reputation.

With historical and popular accounts of the birth of America's missile forces and space programs in the 1950s focused on von Braun's rockets, the Atlas and other air force missiles received relatively little notice. These missiles were developed by a government and contractor team headed by USAF Gen. Bernard Schriever, using cutting-edge systems engineering and management techniques. In recent years, the story of Schriever and his team at the air force's Western

Development Division has attracted interest among historians because of these production innovations.[4]

Once Atlas, Titan, and Thor proved themselves in test flights in 1958 and 1959, they were put into service, starting with Thor in 1958, Atlas in 1959, and Titan I in 1962. Atlas and Thor also began duty as the workhorses of America's space program, launching satellites into orbit and probes to the moon and throughout the solar system. In 1963, the USAF Titan II joined America's nuclear forces, and, along with the Titan III rocket, it became an integral part of America's stable of space launch vehicles. Atlas launched the first four American astronauts to fly into orbit for Project Mercury in 1962 and 1963, and Titan II launched more astronauts for Project Gemini in 1965 and 1966. Although these missiles had relatively short lives as ICBMs owing to their replacement by more effective solid-fueled Minuteman missiles, they remained as mainstays of the US space launch vehicle fleet through the end of the twentieth century.

The question of why the USAF decided in 1954 to build an ICBM has received relatively little attention. As part of widespread political finger-pointing that followed the launch of Sputnik, the air force and the administrations of Harry S. Truman and Eisenhower faced strong political, media, and scholarly criticism for not starting on Atlas before 1954 and for not building it faster. This line of criticism lay behind the best-known and most influential historical analysis of the beginnings of America's ICBM program, Edmund Beard's 1976 book *Developing the ICBM: A Study in Bureaucratic Politics*. Beard argued that the Soviet Union had defeated the United States in the race to develop the first ICBMs, and that the United States could have developed its first ICBM "considerably earlier" than it did, but waited until 1954 to begin its ICBM program while the Soviet Union began work on its ICBM in 1946.[5]

By the last decade of the twentieth century, historians began to reexamine the space and missile races of the 1950s and 1960s in a new and more skeptical light. When the fall of the Soviet Union ended the Cold War in 1991, the veil of secrecy that shrouded Soviet missile and space programs was lifted at the same time as more information became available about American military programs. All this new information shed new light on what decisions were made about missiles, and how and why they were developed. The new interpretations of this history are part of what Launius has called the New Aerospace History, which aims to move beyond concentration on individual rockets or spacecraft to wider social, political, and cultural issues relating to aircraft, missiles, and space vehicles.[6]

Many beliefs about Soviet missile programs that arose at the time of Sputnik were dramatically contradicted by evidence that came to light when Soviet archives were opened in the 1990s, especially the beliefs about the first Soviet ICBM that buttressed the arguments made by Beard and others about the superiority of Soviet missile programs. This book shows how Soviet secrecy and deception helped drive US missile programs while arguing that the ICBMs of both superpowers were created at the same time and for the same reason.

In explaining how the US Air Force came to its decision in the spring of 1954 to build the Atlas ICBM, this work extricates Atlas from the myths that followed Sputnik, with their claims that US missile efforts were well behind those of the Soviet Union. To do so, this book argues that the air force and other military and political authorities had serious reservations about the possibilities of missiles as weapons during the years immediately following World War II. These reservations can be explained in part by the technical, organizational, and political issues that affected nuclear weapons, bomber aircraft, and missile programs. The decision to build an ICBM in 1954 came only after numerous advances in nuclear weapons and missile technologies, political changes in the US government, and even a few technological blind alleys. Contrary to the popular belief fueled by Soviet propaganda that Soviet experts had begun developing ICBMs right after World War II, the Soviet government did not give the green light to creating an ICBM until 1954. Both the United States and the Soviet Union embarked on building ICBMs because of the creation of thermonuclear weapons in the 1950s that were hundreds of times more powerful than the first nuclear weapons, such as those used against Japan in 1945. Histories of the first ICBMs have often passed over this critical fact.

While the requirements of Cold War nuclear weapons have usually formed the backdrop of narratives about the birth of the space technologies, they have rarely garnered the importance they deserve. The relationship between missiles and the nuclear bombs they were designed to carry lies at the center of this account of how the USAF decided to proceed with its first ICBM. Indeed, the technological advances that were necessary to move the technology of rocketry from the troubled V-2s of World War II to the much more sophisticated ICBMs of the 1960s were crucial to making human spaceflight possible, along with all but the smallest satellites and space probes. Without the nuclear confrontation between the Soviet Union and the United States in the 1950s, the history of space exploration would likely have been vastly different.

To explain the air force's approach to missiles in the late 1940s and early 1950s, it is important to examine the state of the first delivery system for nuclear weapons, bomber aircraft, and the problems facing the branch of the USAF charged with delivering those weapons, the Strategic Air Command (SAC). The air force and the rest of the US government had to operate within the political, economic, technological, and social constraints of the time, including tight budgets set for the US military in the five years between the end of World War II and the start of the Korean War. SAC was poorly organized between the two wars, and bomber aircraft had to overcome many technical problems before they could deliver nuclear weapons to targets inside the Soviet Union. These issues have often been ignored by critics who saw air force leaders as overly devoted to their aircraft.

To better illustrate the place of missiles in the USAF in the postwar years, this book examines the air force's struggle to win autonomy from the army, and its subsequent competition with the army and navy to control long-range missiles. The job of creating Atlas fell to the USAF after it bested the US Army in a contest for control of long-range land-based missiles. This is a notable fact because the first long-range ballistic missile, Nazi Germany's V-2, was built by the German Army, and the Soviet Union's R-7 ICBM was built under the supervision of the army until the Soviet strategic rocket forces were created in 1959. In the United States, winning control of the major delivery vehicle for nuclear weapons allowed the USAF to maintain control of nuclear weapons until the navy created its force of submarine-launched ballistic missiles and the army built tactical nuclear weapons and nuclear-tipped missiles designed to defend against enemy aircraft and missiles. As a result of air force control, America's ICBMs were designed and built by contractors with close ties to the air force, rather than being designed in-house by the US Army. The evolution of ICBMs has exercised a powerful influence on the development of America's nuclear weapons and nuclear strategy, making this an important yet disregarded story.

The air force also received outside advice on missiles, and this crucial part of the story is discussed here in far more detail than in previous accounts. As the USAF won its autonomy from the US Army, it sought friendly sources of expert advice about new weapons through a scientific advisory committee and a private think tank with a limited degree of independence, the RAND Corporation. At the same time, the newly created Department of Defense attempted to establish control over the creation of novel military weapons through bodies

such as the Research and Development Board and the Guided Missiles Committee. These bodies enjoyed little success in coordinating military research and development, with implications that went far beyond the matter of missiles.

Long-range missiles quickly became a dual-use technology used for strategic nuclear weapons and to launch spacecraft into earth orbit and beyond. The Soviet Union's space successes based on its first ICBM created incorrect perceptions of the military strength of the two major Cold War adversaries. The marriage of rockets with nuclear weapons was also necessary to move rocket technologies to the point where they could be exploited to carry humans and robots into space. Understanding how and why that marriage took place is essential to understanding the histories of both ICBMs and the space programs these rockets made possible.

1 Weapons of the Future

Early in the morning of June 13, 1944, an unusual flying vehicle emitting a strange noise crossed the English Channel from German-occupied France. It exploded upon impact in the village of Swanscombe in Kent, east of London, just one week after the first Allied troops had landed in France on D-Day. Later that day, three more of the strange winged craft crashed and exploded in southeast England. These were unpiloted aircraft equipped with what was then a new kind of power plant called a jet engine. Over the months that followed, the German Air Force launched thousands of these guided missiles against targets in Britain and Belgium. Each of these missiles, which the German government called the V-1, for the German word for vengeance, were 25 feet long, weighed 4,762 lbs, and were made up of a streamlined fuselage attached to stubby wings and the noisy jet engine that gave the missile its nickname, the buzz bomb.[1]

The German V-1 offensive also quickly led to Allied countermeasures such as antiaircraft guns, fighter aircraft, balloon barrages that reduced the missile's effectiveness, and an attempt to reverse engineer and replicate the V-1. But the German military was ready with another new weapon, which struck for the first time on the morning of September 8, 1944. The world's first long-range rocket missile, the V-2, crashed and exploded without any warning in Paris near the Porte d'Italie a little more than two weeks after the city had been liberated from the Germans. A few hours later, V-2s were launched toward London. The V-2 flew at a much greater altitude, 55 miles; at a far higher speed, 3,600 miles per hour; and had a far longer range, 200 miles, than the V-1 or any existing missile or artillery shell. The V-2 was the product of a highly expensive development effort led by the ordnance department of the German Army. No defenses could stop it once it was launched, and there would be no attempt to replicate the V-2 during the war, because this missile marked such a major advance over anything that had been contemplated by United States or the other Allies.[2]

Even before these two weapons were first employed, British, American, and other Allied forces were aware that the Germans were working on advanced weapons, and Allied bombing campaigns against their development sites and planned launch sites had delayed their use by several months, according to Gen. Dwight D. Eisenhower, the supreme commander of Allied Forces in Europe. "It seemed likely that, if the German[s] had succeeded in perfecting and using these new weapons six months earlier than [they] did, our invasion of Europe would have proved exceedingly difficult, perhaps impossible," Eisenhower recalled a few years later. Neither missile succeeded in slowing the Allied advance, even when the Germans tried to disrupt the shipment of supplies to the Allied forces by bombarding the Belgian port of Antwerp with V-1s and V-2s. The missile attacks continued until March 1945, just weeks before Germany surrendered to the Allies in May.[3]

The introduction of the V-2 and smaller rockets such as the tube-launched bazooka infantry rocket in World War II marked the return of rockets to warfare after having been out of military fashion for nearly a century. Together with the jet-powered V-1, the forerunner of cruise missiles and military drones that came into use later in the twentieth century, these rockets gained prominence as the first of a new type of weapon delivery system: guided missiles. World War II saw the introduction or advance of many technologies that meant big changes in how wars would be fought on land, on the sea, and in the air. This book focuses on guided missiles and particularly on rockets to explain how rockets came to be married to another new technology that did not come into use until the final days of the war.

Rockets and Jets

The appearance of the V-2 marked major changes in the field of rocketry that had been made in the years leading to the war, not by military inventors but by creative people who worked to realize their dreams of flying into outer space. Before the twentieth century, rockets had been fueled only with black powder, also known as gunpowder. Early in the nineteenth century, William Congreve and William Hale in Great Britain introduced technological changes that made rockets more reliable and accurate, increasing rockets' military utility. But that century also saw much bigger advances in other forms of artillery. Because rockets remained without any form of guidance after launch, they were largely sidelined from military uses in the nineteenth century and were used mainly to launch fireworks.[4]

Inspired by speculative novels about space travel written by Jules Verne, H. G. Wells, and others, people began to think at the turn of the twentieth century about using rockets to carry humans into space. In 1903, an obscure Russian schoolteacher named Konstantin Tsiolkovsky wrote a paper suggesting that rockets using liquid fuels and oxidizers could fly far greater distances than gunpowder-based rockets.[5] Although Tsiolkovsky's efforts remained in obscurity for years, others began thinking hard about using rockets to go beyond earth's atmosphere, including Russians such as Friedrich Tsander, whose work inspired other Russians to begin building rockets. Robert Esnault-Pelterie, a French aviation pioneer, independently developed many of the same ideas as Tsiolkovsky and began to publicize them. André Bing of Belgium obtained patents in 1911 for staging rockets. A schoolteacher from Transylvania named Hermann Oberth wrote a book containing technical details for a powerful rocket and a spacecraft capable of carrying humans, stirring up interest in space travel in Germany and central Europe.[6]

In 1919, Robert H. Goddard, a physics professor at Clark College (later Clark University) in Massachusetts, published his ideas on solid rockets, including a suggestion that a rocket could fly to the moon. A press release in January 1920 from the Smithsonian Institution announcing this idea created a worldwide sensation. Goddard had worked for the US Army during World War I on a small rocket, but that work ended unfinished with the 1918 armistice, and after the publication of his 1919 paper, he began a new independent line of research that led to the launch in 1926 of the world's first liquid-fueled rocket. Contrary to popular belief, Goddard did not mind the sometimes critical newspaper coverage of his 1919 paper, but the practical New Englander was strongly concerned about the possibility that others might exploit his inventions without crediting him. Therefore Goddard kept his liquid-fueled rocket research secret for ten years while enthusiasts in France, Germany, Russia, the United States and elsewhere worked independently on liquid-fueled rockets that began to fly in the early 1930s.[7]

Goddard had begun his rocket development work in Massachusetts and continued it from 1930 to 1941 in New Mexico. After famed aviator Charles Lindbergh advocated on Goddard's behalf, philanthropist Daniel Guggenheim and his family financed Goddard's work, which included launching rockets up to an altitude of 9,000 feet. In 1941, Goddard went to work for the US Navy. Other American rocket enthusiasts on the East Coast in 1930 formed the American Interplanetary Society, which later became known as the American Rocket Society,

and some began building and testing rockets. A group of society members set up Reaction Motors Inc. in December 1941, which won military contracts during and after World War II. On the West Coast, the Guggenheim Aeronautical Laboratory of the California Institute of Technology was formed under the leadership of Theodore von Kármán, and in 1936, students and faculty there began work on rockets. The rocket project in the laboratory was transformed in 1944 into the Jet Propulsion Laboratory (JPL), while von Kármán and others from the laboratory also formed the Aerojet Engineering Corporation, later Aerojet General. Both JPL and Aerojet won military contracts during the war to work on rockets.[8]

The two decades between the world wars had seen little military research on rockets in the United States, and Goddard refused to share his findings with other American rocket researchers. The National Defense Research Committee (NDRC), a US government agency set up in 1940 to sponsor military-related research, supported development of solid-fuel rocket engines that led to rockets launched by infantry and from aircraft and ships once the United States entered World War II. The NDRC began its rocket work in 1940 at the suggestion of Clarence N. Hickman of Bell Telephone Laboratories, who had worked with Goddard during World War I. Hickman was associated with the most famous product of the NDRC rocket program, the bazooka, which allowed infantry soldiers to fire against tanks. JPL researchers carried out some of the wartime NDRC rocket work, helping lay the foundation for JPL's work with solid-fuel rockets after the war.[9]

Soviet Rocket Research

Rocket and space travel enthusiasts in the Soviet Union had begun developing rockets and rocket engines starting in the late 1920s, and their activities came under the control of the Soviet military in 1933. In the years leading up to World War II, Soviet rocket research was slowed by low levels of financial support and divisions between the researchers over priorities between solid-fueled, liquid-fueled, winged, and ballistic rockets. Stalin's great purges of 1937 and 1938, which decimated the ranks of the Soviet military and the Communist Party, are now considered to have not greatly affected Soviet rocket research because of the divisions and slow pace of research at the time. Several leading aircraft designers, such as Andrei N. Tupolev, and rocket engineers, most famously Sergei P. Korolev, were swept up in the purges, and while both men survived the terror and the war, a few others were executed. When war clouds

gathered in 1939, Tupolev, Korolev, and many of the skilled prisoners were put to work in prison-based design bureaus, where they spent most of the war. The Soviet Air Force required fighter aircraft to stave off the Luftwaffe more than it needed bombers, so designs for Soviet long-range bomber aircraft languished during the war. The solid-fuel Katyusha artillery rockets were the best-known type of rocket used by Soviet forces during the war.[10]

As the war continued, Korolev and Valentin P. Glushko, Russia's top rocket engine designer who had also been arrested, were allowed to shift from aircraft to rocket design, and in 1944, they were freed while they continued their work. In July 1944, British Prime Minister Winston Churchill wrote Stalin asking for help locating parts from a German V-2 ballistic missile that had crashed in Poland shortly before the Red Army overran the area. Stalin let British and American experts inspect the area, but only after his own forces had scoured it for V-2 parts. As the war came to its end and forces swept over the German rocket research center in Peenemünde, aircraft and rocket experts were dispatched from the Soviet Union to assess the new German technology.[11]

German Rocket Research

In 1930, Wernher von Braun joined other German rocket enthusiasts in launching small rockets while he undertook studies for an engineering degree. In December 1932, the Ordnance Office of the German Army hired von Braun, marking the beginning of Germany's liquid-fuel rocket development program just a few weeks before Adolf Hitler became chancellor of the German government. Under von Braun's technical direction, the growing German rocket organization built a number of rockets in a long and difficult development program, culminating in a rocket initially called the A-4, which was launched successfully for the first time on October 3, 1942, at the German Army's rocket center at Peenemünde on the Baltic coast. This rocket, which became known to the world in 1944 as the V-2, was far more advanced than any other rocket built before it. It was the world's first ballistic missile, a rocket that flew briefly under power before following a ballistic path up to the edge of space and then back down to its target. During the war, the German rocket organization, which had grown to employ about 6,000 people, also carried out some preliminary development work on ballistic missiles that carried wings and more powerful engines to increase their range up to transatlantic distances. In 1943, the notorious Nazi paramilitary organization, the SS (Schutzstaffel), took greater control of the rocket program and employed slave labor from the Dora concentration

camp to build the rockets at an underground factory at Nordhausen in the Harz Mountains in central Germany. As the Allied forces converged on Germany, von Braun and the leading members of his team, under orders from SS General Hans Kammler, drove to the Bavarian Alps, where they surrendered to American troops. Other American troops took control of the Nordhausen plant and its contents.[12]

The V-2 was remembered as a masterful advance in rocketry that opened the door to space. Weighing 14 tons and standing 46 feet high, the V-2 was much larger and more technically advanced than any other rocket that had come before it. But the V-2 was, "in military terms, a boondoggle," according to Michael Neufeld, who has written the most thorough and balanced historical analysis of the V-2. The V-2 program cost about a quarter of the price of America's colossal effort to develop atomic bombs in the Manhattan Project, a sum that if spent elsewhere would have caused far greater damage to Germany's enemies. The five thousand Allied civilians who died in all the V-2 attacks were a fraction of the deaths from single air attacks on Dresden, Hamburg, and other centers in Germany and Japan. The V-1, which cost far less than the V-2, created more terror among the Allies because of the noise it generated as it flew to its targets. And while the V-1 was eventually rendered ineffective because of countermeasures taken against it, those countermeasures cost the Allied forces far more resources than the V-2 did, because there was no defense that could be mounted against the V-2. Although this feature of the V-2 caused American, Soviet, and other militaries to desire similar missiles after the war, the V-2 was ineffective because it was inaccurate—in Neufeld's words, the V-2 "could barely hit a giant city with any certainty." Because the V-2's electronics and navigation systems were not up to the job of directing the missile to a target despite being the best available at the time, the V-2 was deployed too early to be an effective weapon.[13]

Despite the V-2's deficiencies, it contained great advances in the technology of liquid-fuel rockets, which carry both fuel and an oxidizer. Jet engines, which had appeared during the war in the form of the V-1 and small numbers of German and British jet fighters, burn fuel but require oxygen and therefore are limited to operating inside the atmosphere. But because jet engines carry only fuel and not an oxidizer, they are much lighter, less complex, and safer than rockets for use in crewed aircraft. At first, jet-powered missiles like the V-1 appeared to show greater promise to US military leaders and engineers for long-range flights than rockets.

The development of liquid-fueled rockets involved many technical challenges, including highly volatile fuels; designing fuel injectors, combustion chambers, and engine nozzles; maintaining stability as fuel drains out of the tanks; dealing with vibrations characteristic of rocket engines; and requiring high standards for all components in rockets, all of which added to their complexity and cost. There are many types of rockets, but the rockets that appeared in the 1940s and early 1950s were liquid-fueled rockets that used as an oxidizer liquid oxygen, which must be stored at extremely low temperatures. Alcohol was the fuel used in the V-2 and other early rockets, but more powerful fuels such as kerosene became more popular among rocket designers and builders in the 1950s. Later, rockets running on hypergolic propellant combinations that ignite on contact came into use. These propellants contain both fuel and oxidizer and can be stored at room temperature, but they are usually toxic and corrosive. Two key technological problems affecting ballistic missiles such as the V-2 and others that followed the war were the need for a guidance system to take the warhead to its target, and devising a means to protect warheads reentering the atmosphere at the high speeds reached by these vehicles.[14]

Wartime Missile Programs in the United States

Rockets and jet-powered missiles were low on the US military's priority lists during World War II, but not so low that the branches of the military didn't compete to control them. In general, the wartime missile development programs of the US Army Air Forces (USAAF) had been limited to the development of weapons that planners hoped could be quickly built for immediate use, but they were hampered by a lack of central direction, adequate funding and facilities, and qualified staff. In 1943, responsibility for guided missiles within the Air Staff had been given to the air communications officer until shortly before the end of the conflict. Although this officer, Brig. Gen. Harold M. McClelland, held a high rank, he was already burdened with many unrelated responsibilities, as his job title indicates.[15]

When researchers from Caltech proposed developing rocket engines for the military in November 1943, the USAAF turned down the idea, but the US Army Ordnance Department signaled its interest. In January 1944, Army Ordnance asked Caltech to begin work on what became the solid-fueled Private and liquid-fueled Corporal rockets under the ORDCIT (Ordnance / California Institute of Technology) program, along with a smaller version of the Corporal for scientific work called the WAC Corporal. On November 15, 1944, Army Ordnance signed

a contract with the General Electric Company to conduct a rocket and guided missile development project called Hermes, which had the aim of using captured German technology to develop guided missiles and associated technologies. The propulsion technologies included rocket engines and ramjets, a type of jet engine that appeared to hold promise for high-speed aircraft and missiles.[16]

A month after the first V-1 attack in June 1944, one of the German jet-powered missiles landed intact in southern England. This intelligence gift to the Allied forces was quickly handed over to officers from the USAAF. They quickly transported the craft across the Atlantic to their research facilities at Wright Field in Dayton, Ohio, for close examination. Within weeks, the secrets of the V-1 had been revealed, notably that of its pulse-jet engine. Work began on reverse engineering the V-1 and manufacturing an American version, which became known as the JB-2 or the Loon, marking the beginning of the USAAF's guided missile programs. After the defeat of Germany, the USAAF's development work on the JB-2 missile continued with the idea that it could be employed against Japan.[17]

The US Navy, for its part, initiated several guided missile programs during the war, including an adapted version of the JB-2 for launch from aircraft carriers and submarines. It even contracted the Applied Physics Laboratory at Johns Hopkins University to study antiaircraft missiles and a "long-range bombardment missile."[18] The USAAF chafed at the missile programs begun by the navy and Army Ordnance, but it pressed on in 1945 with the JB-2 missile and, more importantly at that time, with other means of bringing Japan to its knees.

The Atomic Bomb

In the Pacific War, the USAAF had bombed sixty Japanese cities with incendiary bombs between March and July 1945, laying them to waste, killing hundreds of thousands of people, and weakening Japan's ability to fight. The United States and its allies were preparing for an invasion of the Japanese islands starting later that year. In July, President Harry S. Truman met in Potsdam with his British and Soviet counterparts and issued a declaration calling on Japan to surrender unconditionally to the United States and its allies to avoid "prompt and utter destruction." The Japanese government declined to reply to the declaration, and Truman's response fell out of the skies over the city of Hiroshima on the morning of August 6. A single bomb dropped by a B-29 aircraft exploded over the center of the city, instantly killing 70,000 people and causing tens of

thousands more to die in the weeks ahead. Sixteen hours later, the White House announced that the weapon dropped on Hiroshima was a new type of bomb, the atomic bomb, which was based on the release of energy contained inside the atom. The Hiroshima bomb was two thousand times more powerful than any bomb previously built.[19]

In announcing the bombing of Hiroshima, the US government disclosed that the atomic bomb had been the result of a large-scale scientific effort that employed top physicists and other experts from the United States and the United Kingdom, along with 125,000 people who built and operated two large production plants and other facilities. "We have spent two billion dollars on the greatest scientific gamble in history—and won," the White House announcement said. An atomic bomb had been exploded at an isolated site in the deserts of New Mexico on July 16, 1945, verifying the concept of nuclear weapons and opening the door to their use against Japan.[20]

Three days after the destruction of Hiroshima, another B-29 dropped an atomic bomb on the Japanese port city of Nagasaki. That same day, Soviet troops poured into Japanese-occupied Manchuria, marking the entry of the Soviet Union into the war against Japan. Under these blows, the Japanese government decided on August 14 to surrender, and with the formal surrender ceremony on September 2, World War II came to an end. From shortly after Japan's surrender to the present day, arguments have continued over whether Japan would have surrendered without the use of atomic bombs, and over Truman's motive for using the bomb. But regardless of the answers to those questions, the US military and much of the American public immediately embraced the new weapon.[21]

The creation of nuclear weapons quickly led to speculation, much of it tinged with concern, about how they might be used in future conflicts. Just two days after the destruction of Hiroshima, an article in the *New York Times* speculated about the impact of the "coupling of atomic-energy explosive with rocket propulsion."[22] Two days later, on August 10, a committee inside the Pentagon charged with coordinating military missile programs reported to the Joint Committee on New Weapons of the Joint Chiefs of Staff about missiles that could be fired against Japan if the war continued into 1946. In case of a protracted war against Japan, the Guided Missiles Committee recommended the deployment of guided bombs under development along with the JB-2 winged missile, and concluded its four-page report with the suggestion that "special consideration be given to the potential value of guided missiles in connection with the use

Museum display of the “fat man” atomic bomb dropped on Nagasaki, Japan, on August 9, 1945. Digital Photo Archive, Department of Energy; courtesy AIP Emilio Segrè Visual Archives

of special explosives [atomic bombs] which should be used with maximum efficiency because of short supply."[23] This document contains the first known suggestion by a responsible body reflecting opinion inside the US military that nuclear weapons be delivered using guided missiles. Even before the end of World War II, the idea of marrying guided missiles to nuclear weapons was under discussion, both in public and in the halls of the US government.

Robert Goddard had spent much of the war working for the US Navy on small rocket projects, notably rockets to assist aircraft during takeoff. In the spring of 1945, Goddard and his team inspected a captured V-2 rocket that had been transported to the United States. Although Goddard believed that the design of the German rocket was copied from the rockets he had built and launched before the war, the secrecy he imposed on his own rocket designs made those similarities purely coincidental. Not long after Goddard saw the V-2, he was diagnosed with throat cancer. His health quickly deteriorated, and he died in a Baltimore hospital on August 10, 1945. Goddard had lived long enough to read in the newspapers about the atomic bombs that fell on Japan. Whether Goddard read or thought about the idea of using rockets to carry nuclear weapons to distant targets is unknown. World War II expired shortly after Goddard, a war that already marked a change from individuals like Goddard building rockets to large institutions like the German Army's ordnance department. The atomic bomb would drive new transformations to the rockets that Goddard had advanced, and other changes awaited in the world that opened up after the war.[24]

2 The Bomb and the Military in the Postwar World

As World War II came to an end, America possessed gigantic armed forces equipped with many of the latest weapons, most importantly the atomic bomb. While these strengths should have left the United States in an enviable position of military superiority, those who were charged with the security of America in the postwar world found that the late 1940s brought a new set of challenges. At a time when many Americans thought they could look forward to a long period with a monopoly on nuclear weapons, the United States possessed only a handful of atomic bombs and had problems enlarging that surprisingly small stockpile. The official government policy on nuclear weapons until 1948 foresaw international control, and President Truman chose to keep America's nuclear weapons out of military hands. The US Army Air Forces negotiated many problems after the war as it struggled to develop the means of delivering nuclear weapons and worked to gain its autonomy from the US Army. Postwar demobilization deprived the USAAF of its best aircrews, and its bomber aircraft could not deliver nuclear weapons to the Soviet Union. Like other branches of the military, the USAAF's budget was cut to a fraction of its wartime level. New aircraft came on stream using technologies such as jet engines with the capability of flying much longer distances than those required during World War II. The Strategic Air Command was created in 1946 and had to transform itself to meet the challenges of a possible nuclear war.

The US military did little to advance missile and rocket technology in the late 1940s, which led in later years to criticism of the air force and the Truman administration for not doing enough to develop nuclear-armed intercontinental ballistic missiles. But to understand the evolution of American military missiles, it is necessary to look at the true states of America's nuclear arsenal and the aircraft available to carry those weapons to their targets. The political context facing US military leaders must also be taken into account. This chapter deals with the political, organizational, and technical problems of the late 1940s that form the backdrop to the story of long-range missiles in the postwar years.

Truman and the Atomic Bomb

To understand the development of nuclear-armed ICBMs, it is important to examine the evolution of nuclear weapons and the politics surrounding them. The world's first atomic bombs were developed in great secrecy during World War II by a scientific, military, and industrial team under the Manhattan District of the US Army Corps of Engineers, which was led by Maj. Gen. Leslie Groves.[1] A group of brilliant physicists and other scientists at Los Alamos in New Mexico designed the weapons under the direction of Berkeley physicist Robert Oppenheimer. The Manhattan Project was cloaked in such secrecy that Truman himself knew nothing about it until Secretary of War Henry L. Stimson and Gen. Groves briefed him thirteen days after he assumed the presidency on April 12, 1945, upon the death of President Franklin D. Roosevelt. Truman did not hesitate to use atomic bombs against Japan in hopes of inducing them to surrender, but debate continues over whether Truman also hoped that the bombs would send a warning to Josef Stalin, the Soviet dictator. The many ambiguities in Truman's handling of US nuclear weapons in the first years after Japan's surrender have contributed to the controversy.[2]

Before he became president, Truman had spent only eighty-two days as vice president after Roosevelt chose him in 1944 as a last-minute compromise candidate acceptable to both the liberal and conservative wings of the Democratic Party. Truman grew up on Missouri farms and had limited success as a farmer and in business. Although he never earned a college degree, he avidly read history books, and his leadership qualities came to the fore when he served as an army artillery officer in World War I in France. After his haberdashery business failed in 1922, Truman became a politician at the county level in the notorious Kansas City political machine of Thomas J. Pendergast. He then served for a decade in the US Senate and overcame his past with the Pendergast machine by leading a wartime Senate committee that investigated military procurement contracts for waste and fraud. As president, Truman was known for his direct manner and populist sensibility that contrasted with the patrician manner of his predecessor. The political turbulence that accompanied America's emergence from hard years of depression and war into the Cold War and the Korean War cost him support through most of his time in the White House. During the postwar years, Truman had to deal with rising prices and labor conflict while questions arose over his ability to lead. Military reverses that lengthened the Korean War reduced his popularity, capped by his highly unpopular decision

President Harry S. Truman, ca. November 1945. US Army; photo by Frank Gatteri, courtesy of the Harry S. Truman Library

to remove Gen. Douglas MacArthur from command in Korea in 1951. But Truman had defied all predictions by winning the presidential election in his own right in 1948, and his popularity rose after he left office in 1953.[3] Although Truman is remembered as a simple man who had no trouble making tough decisions, he was in fact a complex person who like many politicians avoided or postponed difficult choices when possible, as in the case of his treatment of nuclear weapons after World War II.[4]

In 1945, the Soviet Union was officially an ally of the United States, and the following year the Truman administration issued policy statements on nuclear weapons proposing that they be placed under international control. Many US

scientists and political leaders who were disquieted by the toll of the atomic bombs at Hiroshima and Nagasaki proposed sharing information about atomic energy with other countries and establishing an international regime to prevent proliferation of nuclear weapons, while others called for tight government control of all atomic resources to keep them out of the hands of adversaries such as the Soviet Union. The former approach was explored in a US State Department report issued in March 1946 known popularly as the Acheson-Lilienthal Report and officially as the *Report on International Control of Atomic Energy*. The report called for the creation of an international atomic energy authority that would control the mining and production of uranium, thorium, and other fissile materials, along with all nuclear production facilities. Truman appointed well-known financier Bernard Baruch as the US representative to the United Nations Atomic Energy Commission, and Baruch presented a proposal in June similar to the Acheson-Lilienthal plan, but with international inspections of nuclear resources and assets, and no veto for participating nations. As was widely anticipated, the Soviet Union used its United Nations Security Council veto to block the plan in December.[5]

These developments took place in a year noted for deepening antagonisms between the United States and its wartime ally, the Soviet Union. Revelations early in 1946 of Soviet nuclear espionage in Canada and the United States were followed by events that were interpreted as shifting the Soviet Union to a war footing, such as a speech by Stalin, US State Department official George Kennan's call for a harder line with the Soviets in a widely reproduced "long telegram" from Moscow, and Winston Churchill's famous "iron curtain" speech in Fulton, Missouri. Many historians have questioned Truman's commitment to international control of atomic energy, given that Baruch's proposals contained elements that the Soviets would likely oppose. Regardless of Truman's motives, the US policy goal for atomic weapons through 1946 and 1947 remained bringing them under international control. Tensions grew in 1947, when the Truman administration launched the Marshall Plan to aid struggling postwar European economies, and the Soviet Union and its allies rejected this assistance. The Soviet-backed coup in Czechoslovakia took place in early 1948, and differences over the future of Germany came to a head that summer when the Soviets blockaded Western-controlled zones of Berlin. The United States and its allies responded by airlifting supplies into the city. In September, Truman approved NSC-30, a National Security Council paper that ended the policy supporting

international control of nuclear weapons and instead permitted the military to plan for nuclear war, but kept the final say on use of nuclear weapons in the hands of the president.[6]

Not surprisingly, American military leaders were not among those who looked to international control of nuclear assets in the months following World War II. When Baruch asked military leaders to comment on the arms control proposals in 1946, the commanding general of the air force, Gen. Carl A. Spaatz, replied that he believed that the security of the United States would be better served by retaining sole control of the bomb. The air force proceeded on its work with atomic bombs without reference to the possibility that the United States might give up control of the weapons.[7]

Another issue on Truman's desk was the matter of possession and control of the nuclear bombs and components, which in 1945 and 1946 remained in the custody of the Manhattan Project. The US Congress debated competing versions of a bill to control nuclear arms and nuclear energy resources. Truman initially supported the May-Johnson Bill, which provided a strong degree of military control over nuclear assets. Congressional support for the May-Johnson Bill withered when scientists who did not want the military to control nuclear research raised their voices. Early in 1946, Senator Brien McMahon of Connecticut introduced another bill to place nuclear research under civilian control with minimal military involvement. After lengthy debate, Congress passed a bill based on the McMahon proposal, and Truman signed the Atomic Energy Act into law on August 1, 1946. The law established a civilian Atomic Energy Commission and gave it custody of America's nuclear arsenal, effective January 1, 1947. The military could obtain nuclear bombs with the president's approval, but they remained in the custody of the commission. Truman declined several entreaties from military leaders for custody of the weapons until 1951, after the Korean War broke out, when he finally agreed to place some nuclear bombs under military control.[8]

Operating the Atomic Bomb

Even if the air force had won permission to control nuclear weapons immediately after World War II, it faced greater challenges than most people have appreciated in making itself ready to use the atomic bomb if necessary. The United States possessed only one unused atomic bomb at war's end and just one way to deliver this new weapon. By July 1947, the United States possessed only thirteen atomic bombs, and it had fifty a year later. The first atomic bombs

were large, heavy, unwieldy, and complicated, with the Nagasaki "fat man" bomb weighing in at about 5 tons with a length of more than 10 feet and a width of 5 feet. The bombs were difficult to assemble and required special equipment to load into aircraft. The first Mark III bombs, based on the fat man design, had to be assembled shortly before use and disassembled after only a few days in combat-ready status if they were to be used at a later time. These were the main atomic bombs in service until 1949.[9]

The only aircraft in 1945 capable of carrying the weapons were two Boeing B-29 bombers specially modified to carry and drop the bombs, and they were operated by crews specially trained to handle these weapons. The next year, twenty-seven B-29s underwent the structural and weight reduction modifications known as Silverplate to carry atomic bombs. Two fat man bombs were exploded for the July 1946 Operation Crossroads tests on Bikini Atoll, one of them after being dropped from a B-29.[10]

Contrary to popular belief at the time, the United States did not have any atomic bombs ready for immediate use. In April 1947, the leaders of the newly established Atomic Energy Commission informed Truman for the first time about the size of America's nuclear weapons stockpile, and the president was shocked to learn that it had no assembled atomic bombs in stock, and sufficient parts to complete only seven bombs. The high degree of secrecy surrounding nuclear weapons meant that few military leaders knew how many bombs were on hand.[11]

The new commission moved quickly to bring atomic bombs into regular production, but that was much easier said than done. Most of the scientists who worked on the Manhattan Project had left to return to academic life as soon as they could once the war had ended. New bombs needed to be developed and tested to make more efficient use of the highly limited supplies of uranium, which at the time came from one nearly tapped-out mine in the Belgian Congo and another mine in Canada with limited output. The reactors used to produce plutonium in Hanford, Washington, were in a "precarious state" in 1947,[12] and many bomb parts were in short supply. The Sandstone nuclear tests in April and May 1948 yielded new design concepts that modestly increased the explosive power of these bombs and enabled higher production rates owing to more efficient use of plutonium and uranium inside the bombs. Only in 1949, after he came to accept nuclear weapons as the centerpiece of US defense policy, did Truman agree to a major increase in the rate of production of nuclear weapons.[13]

Until well into 1947, "the limitations of the bomb governed U.S. strategy," including the small number of bombs, the limited range of bombers, the superiority of Soviet conventional forces in Europe, the size and demonstrated resilience of the Soviet Union, and questions about how best to use atomic bombs.[14] The newly created National Security Council provided no guidance about the circumstances under which nuclear weapons would be used, leaving the decision and responsibility solely with the president. In addition, Truman kept nuclear weapons out of the hands of the military and under the control of the Atomic Energy Commission until 1951.[15] Truman was criticized for not expediting decisions on the use of nuclear weapons and for lacking a nuclear strategy, but there is evidence that Truman saw the deterrence value from simply possessing nuclear weapons. Noted Cold War historian John L. Gaddis praised Truman's attitude, noting that "one might also argue that Truman was *more* mature than most others at the time because he saw, almost from the start, that nuclear weapons were going to change the meaning of 'strategy' itself."[16]

Airpower

For the USAAF, the technical limitations of the first nuclear weapons were only one of the uncertainties it faced as World War II ended. Despite the presence of the atomic bomb in the arsenal, questions still surrounded the effectiveness of strategic bombardment of enemy cities, industries, and military installations, which the USAAF's leaders saw as the heart of their mission. Although the bombing of Hiroshima and Nagasaki proved it was possible to use bomber aircraft to take nuclear weapons to their targets, the bomber still required a great deal of development before it could become an effective weapon, as the Soviet Union emerged as America's main adversary.

When the air force began in 1943 to prepare for the postwar world, its planners considered Japan and Germany the biggest threats to the United States once the war ended because of their demonstrated ability to use airpower. The Soviet Union, on the other hand, provided a "long-term threat, commencing no earlier than twenty years after the end of World War II" because it did not possess or use long-range bombers during the war. The Soviets' lack of long-range bombers was incorrectly chalked up to the poor state of Soviet technology.[17] USAAF Commanding General Henry H. "Hap" Arnold commented as late as the summer of 1945 on the primitive nature of Soviet technology, which limited its danger to the United States. But USAAF planners had given little thought to the fact that doctrinal factors and immediate defense needs had

moved the Soviets to fighters and light-bombers and away from heavy bombers. Many USAAF officers were already concerned about the Soviets because of the difficulties they had dealing with them as allies. The USAAF had refused to share long-range bombers with the Soviets as it did other equipment during the war. Another illusion held by many air force planners involved the role of the United Nations (UN) as an international police officer in the postwar world, and that belief influenced air force planning until the limitations of the UN became apparent once it was founded in 1945.[18]

Air force concerns about Russia sharpened as the war ended. In the fall of 1945, the USAAF produced its first targeting study of twenty Russian cities. Soon it became clear that the Soviet Union was not demobilizing to the same extent as the US military, leading to concerns among American military planners about the Soviet Union's strength as a European land power. Reflecting growing concerns in Washington over Soviet actions in Europe and its toughening stands in talks with the United States, USAAF Maj. Gen. Lauris Norstad told President Truman in October 1946 that the Soviet Union was "the only probable source of trouble in the foreseeable future."[19]

World War II had been the first real test of the airpower theories that had been developed in the 1920s and 1930s. By war's end, the role and value of strategic bombing remained controversial both inside and outside the military. The arguments focused not only on the overall value of strategic bombing, but also on the value of bombing directed at military targets versus wide-area bombing intended to destroy urban areas and kill large numbers of people with the aim of undermining civilian morale. The United States Strategic Bombing Survey found that "Allied airpower was decisive" in winning the war in western Europe, and that Japan would have surrendered before the end of 1945 under the weight of air attacks, even without atomic weapons or the threat of a Soviet involvement in the war. The survey also found that in both Europe and Japan, "heavy, sustained and accurate attack against carefully selected targets is required to produce decisive results when attacking an enemy's sustaining resources," and that "no nation can long survive the free exploitation of air weapons over its homeland."[20] Air force generals such as Carl Spaatz and Curtis LeMay credited strategic bombing with being decisive in both Europe and Japan, and used this argument to build support for a stronger air force that was independent from the army. Critics countered with assertions that most bombing had proven ineffective, and that by 1944 both Germany and Japan had been seriously weakened by other means. Air force leaders responded to

these criticisms by claiming that true strategic bombing did not begin until late in the war, and that too often bombers had been directed to tactical targets such as submarine pens rather than strategic assets such as synthetic oil facilities.[21]

The controversy extends to the present day, as recent historical assessments question the effectiveness of bombing during the war. While its use in the European and Japanese theaters fell short of the hopes of airpower theorists, strategic bombing made a "major yet expensive" contribution to the war.[22] "Modern economies and societies proved to be surprisingly robust, capable of coping, responding positively to stress, and ultimately withstanding tremendous punishment."[23] But to most of the public in the late 1940s, the arguments about strategic bombing were rendered moot as a result of the atomic bombing of Hiroshima and Nagasaki. "Strategic bombardment had won its case, and the ignored lessons of World War II could remain ignored by the public, Congress, the Air Force, and all others except the inquiring scholar or the parochial Army or Navy man," as historian Perry Smith put it.[24]

Strategic Air Command

Once the war ended, the US Army Air Forces concentrated on demobilizing, with its most experienced and skilled personnel leaving for civilian life because their experience put them first in line to be discharged. A year after World War II ended, the armed forces were cut to a quarter of their wartime strength, with the USAAF reduced by 1947 to one-eighth of its wartime complement. In December 1946, USAAF Commanding General Spaatz estimated that only two air force groups were combat ready, compared to more than two hundred that were operational eighteen months earlier. Not long after, he complained that demobilization "all but wrecked" the air force and added that there "was not left a single squadron with wartime standards of efficiency."[25]

The American public's overwhelming appetite for postwar demobilization was also reflected in the series of tight budgets imposed by the Truman administration with support from Congress. In the 1946 US midterm elections, voters gave majorities in both the House and Senate to the Republican Party, which was eager to lower taxes and reduce spending. The Republican-dominated 80th Congress worked to further cut budgets in 1947 and 1948, and, as a result, the air force faced additional cutbacks in both years. The fiscal year 1947 budget for the War and Navy Departments, including occupation duties in Europe and the Far East, was set at $13 billion, a fraction of the $80 billion spent by

the departments in 1945.[26] By 1950, the Joint Chiefs of Staff estimated that the military needed $23.6 billion for the year, but Truman held the defense budget under $15 billion and contemplated an even smaller defense budget for 1951, at least until the onset of the Korean War. Truman's tight money policies had the effect of increasing the importance of America's limited stock of nuclear weapons because conventional forces were so severely reduced.[27]

Demobilization and tight budgets formed the backdrop to a 1946 reorganization where the USAAF replaced its regionally based combat commands with functional ones: the Strategic Air Command, Tactical Air Command, and the Air Defense Command. Gen. George C. Kenney, who had commanded air forces in the Pacific theater, became the first commander of SAC. With the best pilots and crew already discharged, SAC faced the challenge of operating with large numbers of poorly trained and inept pilots and mechanics, and problems in obtaining the skilled personnel it needed to build a striking force. As well, Kenney spent much of the year on duties related to USAAF public relations and the United Nations. His deputy, who had effective charge of SAC, instituted an unpopular and ineffective program to train aircrews for various jobs both inside and outside the aircraft. Kenney and his staff reorganized SAC in a bid to make it more efficient, but the reforms had mixed success.

The B-29 bombers that the USAAF had used to such great effect against Japan in the final months of World War II represented an increase in range over any other bombers used during the war. But they still could not reach the Soviet Union from the continental United States, and so the USAAF could only respond to any Soviet aggression with strategic air strikes from bases in Alaska, England, Japan, and North Africa. SAC's efforts to establish foreign bases were frustrated by political issues such as the need to get permission from host governments before launching attacks, and logistical questions such as supplying parts and provisions far from home. Initial attempts to base bombers in the arctic climate of Alaska were stymied by the unforgiving cold and the major navigational problems found in the north.[28]

The USAAF intelligence division warned in 1947 that significant obstacles stood in the way of choosing and finding bombing targets inside the Soviet Union. Many important targets lay deep inside Soviet territory, beyond the reach of armies, naval-based arms and aircraft, and all but the longest-range bombers. Even more important, the United States had little information about potential targets and target areas. While captured German photographs and maps

gave the Americans good information about Soviet territory occupied by the Germans during World War II, no such information existed on territory farther inland, where many important Soviet military installations were located. Soviet secrecy made the position of many military facilities difficult for outsiders to determine. SAC bombers attacking the Soviet Union would also need to overcome Soviet defense measures that the aircraft used to drop the bombs on Hiroshima and Nagasaki did not have to face.[29]

The Air Force's Place in the Military

On top of the other changes the air force faced in the first two years after the war, it also saw its place in the US military transformed. The US Armed Forces saw unprecedented growth during World War II, and the changes that war brought to the world—particularly the enlarged role of the United States in world affairs—meant that the US military did not return to its sleepy peacetime existence of the 1920s and 1930s. Discussions began during the war about changing the structure of the US military, culminating in a reorganization that formally took place in 1947. The reorganization process included what journalist Robert J. Donovan called "the worst feud among the armed forces that the United States has ever known."[30]

Before and during World War II, the US military had been organized under two departments. The Department of the Navy contained the US Navy and the US Marine Corps, and the Department of War controlled the US Army. Both the army and navy obtained aircraft early in the century, and the army's air assets gained autonomy over time, starting in 1907 when the Army Signal Corps set up an Aeronautical Division.

The idea of making the air force a separate branch of the armed forces had originated in the 1920s, when Brig. Gen. Billy Mitchell agitated for an autonomous air force outside the army. Mitchell not only failed in this effort but was also court-martialed for his criticism of army leaders. Despite these rebuffs, the desire for an autonomous air force remained strong among the flyers and grew during World War II. On the eve of war in June 1941, the Army Air Corps, as it then was known, was upgraded to the USAAF, and USAAF Commanding General Arnold was admitted to the newly created Joint Chiefs of Staff, moves that appeared to foreshadow an autonomous air force. At that point, the US Army was composed of the Army Ground Forces, the Army Air Forces, and the Army Service Forces. The war saw the creation of some unified commands involving all the services, but President Franklin D. Roosevelt found himself

personally adjudicating disputes between the army and navy, particularly in the Pacific theater.

In 1943, US Army Chief of Staff Gen. George C. Marshall proposed unifying the military as a means of encouraging unity of command and reducing duplication. The unified military would have ground, air, and naval branches. The idea was not new because Congress had considered but rejected military unification in 1932 as an economy measure. Following Marshall's proposal, a committee of the House of Representatives held hearings in 1944 into military unification. When the war ended in 1945, the army promoted unification while the navy resisted the idea, and these contrasting viewpoints were raised in Senate hearings that fall.[31]

The debate on armed forces unification began in earnest when Truman sent a message to Congress in December 1945 calling for the armed forces to be transformed from two separate departments into a single department of national defense. The new department would have three coordinated branches for the army, navy, and air force, each headed by an assistant secretary serving under the secretary of national defense. Because there was no political support for creating a third military department for the air force alongside the war and navy departments, the USAAF's hopes for independence from the navy and the army rested on unification of the armed forces in one department with three equal services. Truman's plan, however, sparked conflict within the military.[32]

The long effort by the air force's leading figures to separate from the US Army had been strongly resisted by the US Navy, which feared losing its air arm. The navy had deliberately avoided creating a separate air division to protect its aviation assets, which it saw as "an indispensable element in naval warfare," from being shifted to a separate air force. It "bitterly opposed" unification in general sense, because it feared losing the US Marine Corps to the army.[33] The navy's concerns were based in part on the precedent of Britain's Royal Air Force (RAF), which when founded in 1918 absorbed both the British Army's tactical air units and the Royal Naval Air Service. Billy Mitchell had advocated a similar vision for an air force in the United States. But the navy also feared that even if the army and navy air arms remained in place and a separate air force concentrated on strategic missions with atomic weapons, naval aviation would face severe cutbacks during peacetime because money and support would flow to a nuclear-armed air force. The navy's concerns about air force use of nuclear weapons ran deeper because naval leaders had different ideas about how to use nuclear weapons, including opposition to the air force plan to use atomic bombs against

large population centers. The air force, in turn, looked with unease on the navy's air assets, which it saw as cutting into its mission.[34]

Most of the army strongly supported unification in the belief that a single defense department would insulate the army from political pressures to divert funding to the more glamorous air force and navy in times of peacetime retrenchment. The feeling was especially strong among those, like Marshall, who remembered the stalled army careers of the interwar years and did not want to repeat the experience.[35] Concerns about an autonomous air force were strongly felt, however, within the ranks of Army Ordnance, which was part of the Army Service Forces and would compete with the air force for control of missiles. Army Ordnance Maj. Gen. John B. Medaris, who commanded the army's missile program in the 1950s, believed that the Ordnance Department's future lay in missiles. Medaris and his colleagues were no doubt aware that ordnance departments, not air forces, in the German Army in World War II and the postwar Soviet Red Army had responsibility for ballistic missiles.[36]

The debate over Truman's unification bill ran for months in Congress, where the army, navy, and air forces had strong representation in the form of friendly members of Congress who had military installations in their states and districts, or had built up relationships with the individual military services through committee work. The National Security Act that Truman signed into law on July 26, 1947, was a compromise that departed from his proposal of December 1945. Instead of a department of defense, the law created a secretary of defense who with a small staff presided over the small and weak but grandly titled forerunner to the defense department known as the National Military Establishment. The Departments of the Army, Navy, and Air Force were run by secretaries who had seats at the cabinet table and a great deal of power. The result was that the interservice struggles that preceded unification continued unabated.[37]

The US Air Force gained its independence under the National Security Act on September 18, 1947. Although the event marked the successful completion of efforts to create an autonomous air force, it did not mean an end to challenges to its jurisdiction, particularly in the field of missiles. Because the air force's mission statement was vaguely worded and because of the tight budgets being imposed on the military at the time, disputes continued at the highest levels between the services and Secretary of Defense James V. Forrestal, who had few means at his disposal to resolve them.[38]

Curtis LeMay

The early months of the USAF coincided with deepening Cold War tensions between the United States and its erstwhile World War II ally, the Soviet Union. The communist seizure of power in Czechoslovakia in 1948 drove home to many Americans the severity of the Soviet threat. Late in June 1948, the Soviet government blocked rail and road access through the zone of Germany it controlled to the zones of Berlin controlled by the United States, Britain, and France. The Western allies responded with the Berlin Airlift, and that summer Truman authorized additional B-29 bombers to be deployed to Britain and Germany. No atomic weapons or bombers capable of carrying them were moved to Europe, and the only bomber group capable of delivering nuclear bombs remained in the United States but went on twenty-four-hour alert. The USAF was concerned about the use of its cargo aircraft in the crisis because those aircraft usually supported its nuclear-armed bomber fleet and wouldn't be available for that purpose in a time of high tension.[39] The Berlin Airlift continued until the following May, when the Soviets acknowledged its success by lifting their blockade. The moves sent a message to the Soviets but also raised questions among American policymakers. Despite pleas from military leaders, Truman kept atomic weapons under civilian control, and he declined to indicate when or under what circumstances he would release those weapons to the military. This fact also complicated military planning. The United States' first emergency war plan of the post–World War II period had only been drawn up a few weeks before the Berlin Airlift began, and it was incomplete in many respects.[40]

When Gen. Hoyt S. Vandenberg became USAF chief of staff in 1948, he was deeply concerned about SAC's state of readiness for war, in part because of the crisis in Berlin as well as a critical report on air force combat readiness prepared by famed aviator Charles A. Lindbergh. Vandenberg responded in October by appointing Maj. Gen. Curtis E. LeMay as SAC's commander. If anyone personified the USAF in its early years to both its supporters and detractors, it was Curtis LeMay. During World War II, he quickly rose through the ranks as he developed effective bombing techniques in the European theater, and between March and July 1945, he directed the firebombing that laid waste to sixty Japanese cities and killed hundreds of thousands of Japanese civilians. LeMay led SAC for nine years and then served as the USAF's chief of staff from 1961 to 1965. The cigar-chomping general became famous for his aggressive support of strategic bombing with nuclear weapons, and for his statement that the US

A giant B-36 appears with its newly adopted jet pods, each of which carries two engines, for a total of four. This photograph was taken during a demonstration for President Harry S. Truman at Eglin Air Force Base in Florida. US Air Force; courtesy of the Harry S. Truman Library

military should bomb North Vietnam "back into the Stone Age." His notoriety was sealed in 1968 when he ran for vice president as the running mate of Alabama segregationist George Wallace.[41]

In his early months commanding SAC in 1948 and 1949, LeMay worked vigorously to eliminate what he saw as SAC's organizational, logistical, and morale deficiencies. He was determined to end lackadaisical peacetime routines and to bring his aircrews to a state of full preparedness as if it were wartime. Before he began new training programs, LeMay gave his command a graphic demonstration of how unprepared they were for their mission when, in January 1949, he organized a mass simulated bombing exercise over Wright Field at Dayton, Ohio. LeMay later wrote: "Not one airplane finished that mission as briefed. *Not one*." Aircrews were not accustomed to flying as high as the required altitude of 30,000 feet, and this failed exercise led to an aggressive training

program. Instead of the leisurely peacetime routine that had existed before and after World War II, LeMay made sure that SAC was prepared for a war that could start the next morning.[42]

LeMay also was concerned about the capabilities of his bombers. The air force had finished the war with a fleet of propeller-driven aircraft that could not cover the great distances required to reach targets inside Russia from bases in the American mainland. The arrival late in the war of the first aircraft equipped with jet engines meant that the air force and contractors had to learn how to build, maintain, and use the new engines, and operate aircraft at the high speeds they made possible. It was only in October 1947 that an aircraft flew faster than the speed of sound, and years of work lay ahead before aerodynamics at supersonic speeds would be understood.[43]

In the meantime, LeMay had to deal with the limitations imposed by the bombers he had on hand. To get around the political problems involved with foreign bases for SAC's fleet of B-29 bombers and the more powerful version of the B-29 designated as the B-50, LeMay sought to increase their range with new in-flight refueling technologies and tanker aircraft. He also pressed for the development of longer-range bombers capable of delivering bombs directly from the United States to the Soviet Union despite the many technical difficulties that stood in the way of that goal. The first aircraft that had this capability was the B-36, which entered service in 1949 after a difficult development process. The first jet-propelled long-range bomber, the B-47, also experienced some problems with its development before it came into service in 1951. The B-52, which became the mainstay of US bombing capability for decades, came into service four years later.[44] The questions hanging over the basing of US bombers in Europe were reduced in 1949, when the United States signed the North Atlantic Treaty with Western European nations and Canada. The creation of the North Atlantic Treaty Organization provided a political basis to continue the US military presence in Europe, including bombers.

Thanks to better training, aircraft, and the new bases, SAC markedly improved its ability to deliver atomic bombs in 1949. By 1950, SAC had 225 bombers capable of dropping atomic bombs, including B-29s, B-50s, and 34 of the new B-36s. The command had 263 combat ready aircrews and 18 bomb assembly crews. More aircrews and assembly crews were being trained.[45] Despite this work, the air force's ability to deliver a crippling blow to the Soviet Union was questioned by US Navy critics in 1949 as well as in two military reports the following year that were drawn up amid concerns about the growing power of the Soviet

Gen. Curtis LeMay in the 1960s. US Air Force

Union. The Joint Chiefs of Staff's weapons evaluation group completed a report on strategic bombing in February 1950 that warned of logistical deficiencies in SAC, along with the possibility of a high rate of bomber loss in part owing to lack of information on Soviet defenses against bombers. In May, a committee of top military officers headed by air force Gen. Hubert R. Harmon completed a study into how much damage America's nuclear arsenal could deliver to the Soviet Union. It determined that strategic bombing could seriously damage the Soviets but questioned whether this damage would result in surrender or weaken the government.[46] Even with LeMay's reforms to SAC, the US Air Force still faced major challenges in developing the means to attack the Soviet Union with bomber aircraft.

From 1945 and through most of the 1950s, the air force's strategic bombing function was based exclusively on bomber aircraft carrying nuclear bombs. During those years, the air force's real capability to attack the Soviet Union with bomber aircraft did not match its potential capability.[47] Realizing that its existing aircraft and aircrews were not up to the task of performing their central mission of carrying nuclear bombs into the heartland of the Soviet Union, the air force concentrated its limited financial resources in the late 1940s on correcting this deficiency. This included training and motivating its personnel, developing new and better aircraft, and devising new methods of extending the reach of those aircraft through forward basing outside the continental United States and through advancing the art of midair refueling. Under the tight budgets of the late 1940s, these proved to be big jobs that preoccupied the air force.

3 Missiles in the Postwar Years

In the years that followed World War II, the US government and industry sought to exploit the technologies that were advanced or created during the war. American military and intelligence agencies took advantage of the wartime work of German scientists in various fields, including radar, jet aircraft, rockets, communications, and industrial processes for synthetic rubber and fuels.[1] In the case of rockets, the US Army Ordnance Department obtained Germany's stock of V-2 parts and the services of the engineers who had developed the missile. General "Hap" Arnold and the USAAF sent a group of experts to Germany and elsewhere in Europe as the war ended to collect information on technical advances in aircraft, missile, and other military technologies. The US Navy also sought to benefit from the new technology of missiles by developing its own scientific rocket and missiles for shipboard use. These intelligence efforts helped create the foundations of US missile programs, including the first American ICBMs.

Even as these missile programs began in the final months of World War II, Army Ordnance and USAAF were competing to control military missile programs. Until the creation of the US Air Force in 1947, this competition took place inside the War Department, although the navy generally supported Army Ordnance against the USAAF. The USAAF commissioned experts to look into potential missiles, and their work showed several different possibilities, including rockets with and without wings, and missiles propelled with ramjets or nuclear engines. The idea of ballistic rocket missiles was just one of these options available in the late 1940s to the US military.

Higher Authorities

In the early months that followed the war, missiles received high-level attention from two committees of the Joint Chiefs of Staff (JCS). In November 1945, the JCS's Guided Missile Committee's first proposed policy for a national guided

missiles program went to the Joint Committee on New Weapons. The policy argued that, in the future, "guided missiles must evolve along lines dictated by the probable future development of atomic energy both in the warhead, and, more remotely in the future, as a potential propellant for the missiles themselves." The eight-page policy report predicted that the evolution of future missiles would be dependent on developments in atomic power, supersonic aerodynamics, guidance systems, launch systems, and "ram-jet and other propulsion schemes." The report called for missiles capable of destroying aircraft and other missiles, "missiles for precision attack at short, medium and long ranges," missiles "for area attack guided with precision appropriate to the lethal range of various warheads, and covering ranges up to thousands of miles," and coastal defense and shipboard missiles. While the policy stressed the need for basic and applied research to make advanced missiles possible, it warned that "there will always be a limited supply of first class scientists and engineers," which meant that development must not be rushed ahead of knowledge.[2] Chief of Staff Admiral William Leahy approved the document for the joint chiefs on March 23, 1946, and Secretary of War Robert Patterson ratified it shortly afterward, making it military policy.[3] The new policy was so vague that it had little more effect than to encourage the services to proceed with their own research and development of guided missiles, and it did not lead to any coordination of the services' missile programs. Nor did it have any impact on the services' escalating jurisdictional disputes over missiles. With the navy, the USAAF, and Army Ordnance all involved in the area, guided missiles remained contested terrain.

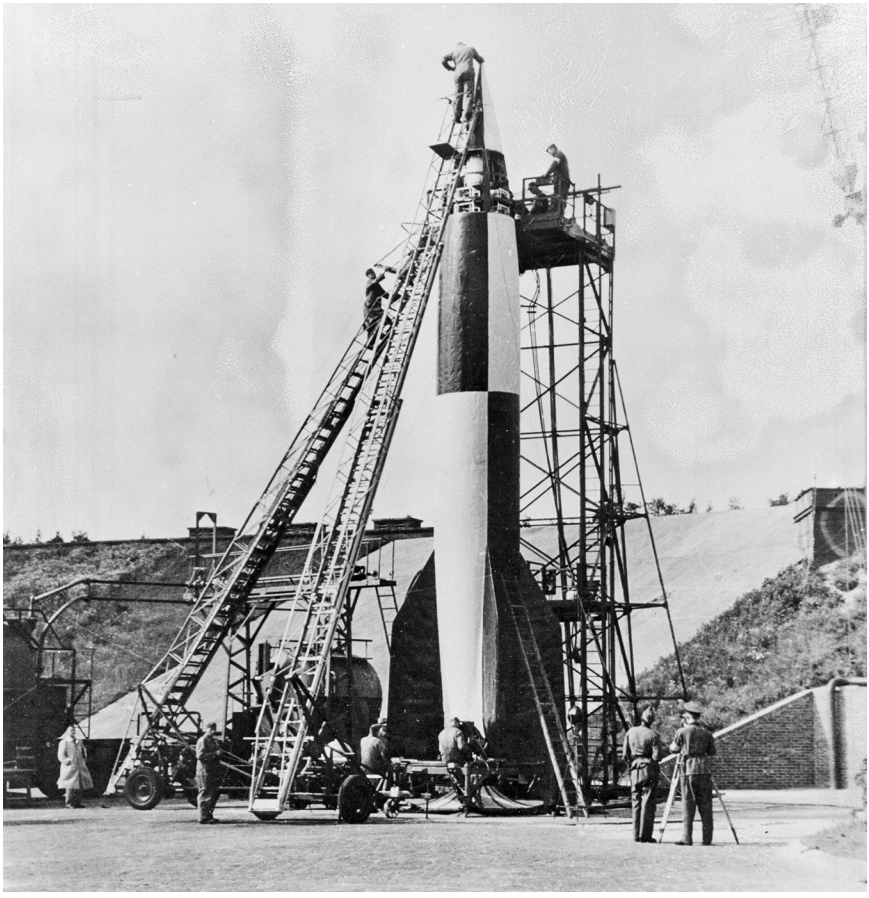
In January 1946, another committee in the Pentagon weighed in on missiles. The report of the War Department Equipment Board, which was formed to review what new weapons and other equipment would be needed in the postwar environment by the US Army, including the Army Air Forces, called for the development of several kinds of guided missiles, including missiles to defend against enemy aircraft and missiles, and "strategic" missiles carrying "atomic explosive" intercontinental distances at high speeds and altitudes that would be "incapable of interception with existing equipment." The board, which was chaired by Gen. Joseph W. Stilwell, who had commanded American forces in the China-Burma-India theater in the war, pointed to the need for research on guidance systems for missiles and on various forms of propulsion, including methods using nuclear energy.[4]

Germans in the Desert

Even before the war had ended, the services had begun to ramp up their work on rockets and other missiles. Army Ordnance worked with engineers from the Jet Propulsion Laboratory at Caltech in the final months of the war on missile programs and with the General Electric Company in the Hermes Project. When the war in Europe ended in May 1945, the army became aware that the core of the team that had developed the V-2 was available for exploitation by the American military, and so were large quantities of V-2 parts and plans. Experts from the army and GE were dispatched to Europe, and that summer the rocket parts, plans, and partially assembled V-2s were shipped to the United States. Army Ordnance hired about 120 German rocket engineers after they surrendered to American troops at war's end, and assigned them to work in Hermes.[5]

In October, Wernher von Braun, then 33 years old, the former technical director of the German Army's rocket team, arrived by train in El Paso, Texas, near the US Army installation at Fort Bliss, where he and the Germans who joined him later in 1945 and early 1946 were quartered in spartan wooden buildings. The Soviet, English, and French militaries sought German experts to share the technical expertise they developed before and during the war, and the US military set up Operation Overcast, later renamed Operation Paperclip, to hire thousands of German engineers and scientists from various fields to exploit their knowledge and, more importantly, to keep that knowledge out of the hands of rivals such as the Soviet Union.[6]

The German rocket experts were put to work writing reports and answering questions about their work in Germany, and the Americans were interested in not only the V-2 but also concepts the Germans had developed to upgrade the V-2 to a transatlantic range, as well as an antiaircraft missile called Wasserfall. When the Germans joined the army and GE experts at the White Sands Proving Ground in New Mexico, north of El Paso, the Hermes Project grew to include work on a surface-to-air missile similar to Wasserfall, a ramjet test program that utilized captured V-2 missiles for test flights, and a short-range surface-to-surface missile that evolved into the army's Redstone intermediate range ballistic missile in the 1950s. At White Sands, the Germans worked on assembling V-2s, preparing them for launch, and training army and GE crews to launch them. The first V-2 launched on American soil flew on April 16, 1946. Although the Germans moved to background roles in the V-2 launching work after the first few months, seventy-two V-2s were launched from White Sands



This undated photograph shows German technicians stacking the various stages of the V-2 rocket. Many members of the team of German engineers and scientists who developed the V-2 came to the United States at the end of World War II and worked for the US Army at Fort Bliss, Texas, and Redstone Arsenal in Huntsville, Alabama. 1944. NASA ID 9132003, Marshall Space Flight Center

and other sites in the United States, including a new launch site on the Atlantic Ocean at Cape Canaveral, Florida, between that date and September 1952.[7]

The ramjet was one of three new forms of propulsion the US Army, Navy, and Air Force were researching in the late 1940s, along with rockets and nuclear propulsion. Among the various types of jet engines, the one most commonly encountered today is the turbojet, where air entering the engine is compressed, mixed with fuel in a combustion chamber, and passed through a turbine that

powers the compressor and then through a nozzle to generate thrust. Ramjets don't have compressors but use the forward motion of the engine to compress the air entering the engine. In 1945, this type of engine offered what appeared to be an appealingly simple means to propel missiles without the cost and complications of rockets. But ramjets could not work until they were boosted to high speeds, usually by another engine.

The German rocket experts in Hermes were put to work on ramjet research even though they were experts on rocket engines, not ramjets. Moreover, the tight military budgets of the late 1940s also meant that there was little money for Hermes or the army's other rocket research. The Germans and the other personnel working in Hermes had to make do with slow launch rates and facilities that were primitive and poorly maintained. Many of the missiles built and launched under Hermes were dedicated to ramjet research, but the difficulties with this method of propulsion proved greater than expected, and the army never pursued ramjets after Hermes ended in 1954.[8]

The presence of the German rocket engineers on American soil was kept secret until late 1946, and during their early months in the United States, the Germans worked on short-term contracts and could not leave military installations without a military escort. The Germans' value increased as the Cold War between the Soviet Union and the United States deepened in 1946 and 1947, and the restrictions on the Germans were loosened. The army offered them longer-term contracts, permitted them to work toward American citizenship, and allowed their families to join them. But as time went on, the Germans were increasingly removed from the daily work of the Hermes Project.

In January 1947, von Braun addressed a Rotary Club in El Paso about the future of rockets, and the positive response he received marked the beginning of von Braun's work popularizing space flight in the United States as a speaker and writer on the topic. Aside from work on rocket guidance systems, the Germans did little in the late 1940s to advance the art of rocketry. One reason was the tight military budgets of the time, and another was the fact that the Germans' many failures while developing the V-2 caused them to be conservative when it came to new engineering ideas.[9] Von Braun's biographer Michael Neufeld noted that although this conservative approach would serve von Braun well in the future, he and the other Germans were "often not on the cutting edge of rocketry in the United States" during their first decade there.[10]

In addition to the ramjet research, the refurbished V-2s launched by the US military from 1946 to 1952 had many other purposes. In work coordinated by

military, academic, and industry scientists, V-2 rockets fitted with research equipment probed the upper atmosphere and the lower reaches of outer space, photographed the earth from high altitudes, and looked at the sun. Eight of the V-2s carried JPL-built WAC Corporal missiles as second stages as part of Project Bumper, including a 1949 shot that set an altitude record of 244 miles. Some V-2s were allocated to flights of animals under the air force's Project Blossom to gather information for future human flights. Although V-2s were shared with other services, the army's role in launching the largest rocket available in the late 1940s buttressed its claim to build bigger and longer-range missiles.[11]

Germans on the Steppes

As it swept across eastern Germany in the closing days of World War II in 1945, the Red Army occupied the former headquarters of the German rocket program in Peenemünde. Although many German rocket engineers, including their leaders, chose to surrender to American forces, others agreed to work with the Soviets. The Soviets set up an operation in Germany to work with German experts to exploit rocket and other technologies, including nuclear technology and aircraft engines. The leading rocket engineer to join the Soviets was Helmut Gröttrup, who was involved in developing the V-2's guidance, control, and telemetry. Russian engineers, including Korolev and Glushko, came to Germany to help exploit rocket technology, and during this time, Korolev's talents as a rocket engineer and manager became known.[12]

The Soviets invited German experts in various fields to parties on October 21, 1946, that went well into the night. At four o'clock the next morning, more than 2,552 German experts, including 302 involved in missiles, were ordered onto trains that carried them and their families to Russia. Although the German rocket experts continued to work alongside Russians in the months that followed and played a key role in launching V-2s starting in October 1947 at the new Soviet launch site at Kapustin Yar, near Stalingrad, the Germans were increasingly made to work separately from Soviet engineers, and in 1948, the entire German rocket group was moved to an isolated location nearly 200 miles from Moscow. As the Germans' separation from the Russians and from outside information on scientific advances continued, their value to the Soviet program fell. All but a handful of the Germans were returned to East Germany by the end of 1953, and American intelligence officials quickly interviewed them. Because they had been separated by then from the Soviet missile program for

five years or more, the information they had for the Americans was of little value.[13]

In 1945, Stalin read a report on a rocket-powered long-range antipodal bomber written for the German military by Austrian rocket engineer Eugen Sänger and his mathematician wife, Irene Bredt. This prompted Stalin to commission the air force to work on a Soviet antipodal bomber. A scheme in 1948 to kidnap Sänger from his postwar home in France failed when Georgi A. Tokaty, the aviation engineer sent to carry out the task, defected to the West. By then, the plans for the bomber were foundering because of the great difficulties involved in building such a craft, and Tokaty's intelligence value was also limited because he was not involved in the missile program, which was controlled by the army.[14]

The Viking Rocket

The two German rocket weapons of World War II also attracted the attention of the US Navy, which at war's end worked to adapt the USAAF version of the V-1 winged missile for naval purposes. In 1947, the navy launched a V-2 from the deck of a ship to prove the concept of launching large rockets from ships. In 1948, the navy also began designing a long-range missile, the Triton, that never went into production. In the 1950s, the navy developed the Regulus, a winged missile capable of launch from ships and of carrying nuclear weapons 500 miles. And while the navy's work with solid-fueled rockets dated back to World War II, the program that led to the Polaris Submarine-Launched Ballistic Missile did not begin in earnest until 1955.[15]

The navy's best-known rocket program in the decade following the war was Viking, which was designed to provide a superior alternative to the V-2 as a launch vehicle for larger scientific payloads. Viking was one-third the size and the power of the V-2, but it had a lighter structure and more sophisticated control systems, making it a superior platform for scientific experiments. The Naval Research Laboratory gave the Viking contract to the Glenn L. Martin Company, an aircraft contractor looking for work after the war, and its engine was built by Reaction Motors Inc., a firm set up by members of the American Rocket Society. Starting with a first flight from White Sands in May 1949, Viking had a generally successful run of twelve launches through 1955, but along the way the Viking team learned the usual hard lessons about rockets. Viking 4 soared more than 100 miles high after being fired off a navy ship in the Pacific. Viking rockets broke the V-2's single-stage rocket altitude record, and the

Viking experience informed the navy team that built the Vanguard satellite launch vehicle. Martin worked on Vanguard and later became prime contractor for the air force's Titan and Titan II ICBMs.[16]

USAAF Scientific Advisory Group

Arnold, the USAAF's commanding general during the war and the first months that followed, was one of the first military aviators in America thanks to flying lessons from the Wright brothers. Arnold had worked in World War I on a primitive remote-controlled aircraft called the Bug and even thought of producing a similar craft shortly before America entered World War II in 1941. Arnold's experiences in World War II further convinced him of the importance of new weapons and strategies. Although recent scholarship has suggested that Arnold's deficiencies as a manager slowed the development of air force missiles during World War II, Arnold's reputation as a technological pioneer rests on his efforts in the months before his retirement early in 1946 to prepare the air force for the postwar world.[17]

The rocket was prominent among the many new technologies related to the air force's mission at the end of World War II. In his public report to the secretary of war in November 1945, Arnold wrote that new types of rockets becoming available included "winged missiles for extreme range," antiaircraft missiles, and rockets to launch and decelerate aircraft. In anticipation of improved defenses against bombers and ballistic missiles carrying nuclear bombs, Arnold called for the United States to be ready with weapons such as the V-2 that could frustrate those defenses. Arnold said possible defenses could also include "true space ships, capable of operating outside the earth's atmosphere," whose design is "all but practicable today; research will unquestionably bring it into being within the foreseeable future."[18]

At the time Arnold wrote this report, he was already well along in his efforts to ensure that the USAAF had the best scientific advice available. These endeavors included the creation of an advisory group of experts that pulled together knowledge about technological advances made by the United States, its allies and adversaries in World War II, and later an outside body of experts under corporate auspices that began to investigate issues of interest to the air force.

In September 1944, Arnold asked Caltech professor Theodore von Kármán, one of the world's top aviation theorists, to lead a group of experts from government, academia, and business known as the Army Air Forces Scientific Advisory Group to prepare a long-range study program that could guide the

Gen. H. H. Arnold (*right*) turns over the command of the Air Force to Gen. Carl Spaatz, February 1946. US Air Force; courtesy of the Harry S. Truman Library

air force for the next ten to twenty years. Arnold formally launched the study two months later, on November 7, stating his beliefs that the United States' prewar research had been inferior to that of other nations, that offensive rather than defensive weapons win wars, and that the American public would not be willing to support a large standing army. He then asked, "Is it not now possible to determine if another totally different weapon will replace the airplane? Are manless remote-controlled radar or television assisted precision military rockets or multiple purpose seekers a possibility?"[19]

A colorful Hungarian who loved the good life and was doted on by his mother and a sister for much of his life, von Kármán dedicated his career to aviation after seeing his first aircraft in 1908, less than five years after the Wright brothers first flew. On the eve of World War I, he became director of the Aachen Aerodynamics Institute in Germany. After his work was interrupted by the war and a sojourn back in Hungary following the armistice, von Kármán returned to

Theodore von Kármán sketches out a plan on the wing of an airplane as his jet-assisted take-off (JATO) engineering team looks on in 1941. *From left to right*, Clark B. Millikan, Martin Summerfield, Theodore von Kármán, Frank J. Malina, and pilot Capt. Homer Boushey. Capt. Boushey would become the first American to pilot an airplane that used JATO solid-propellant rockets. AIP Emilio Segrè Visual Archives, *Physics Today* Collection

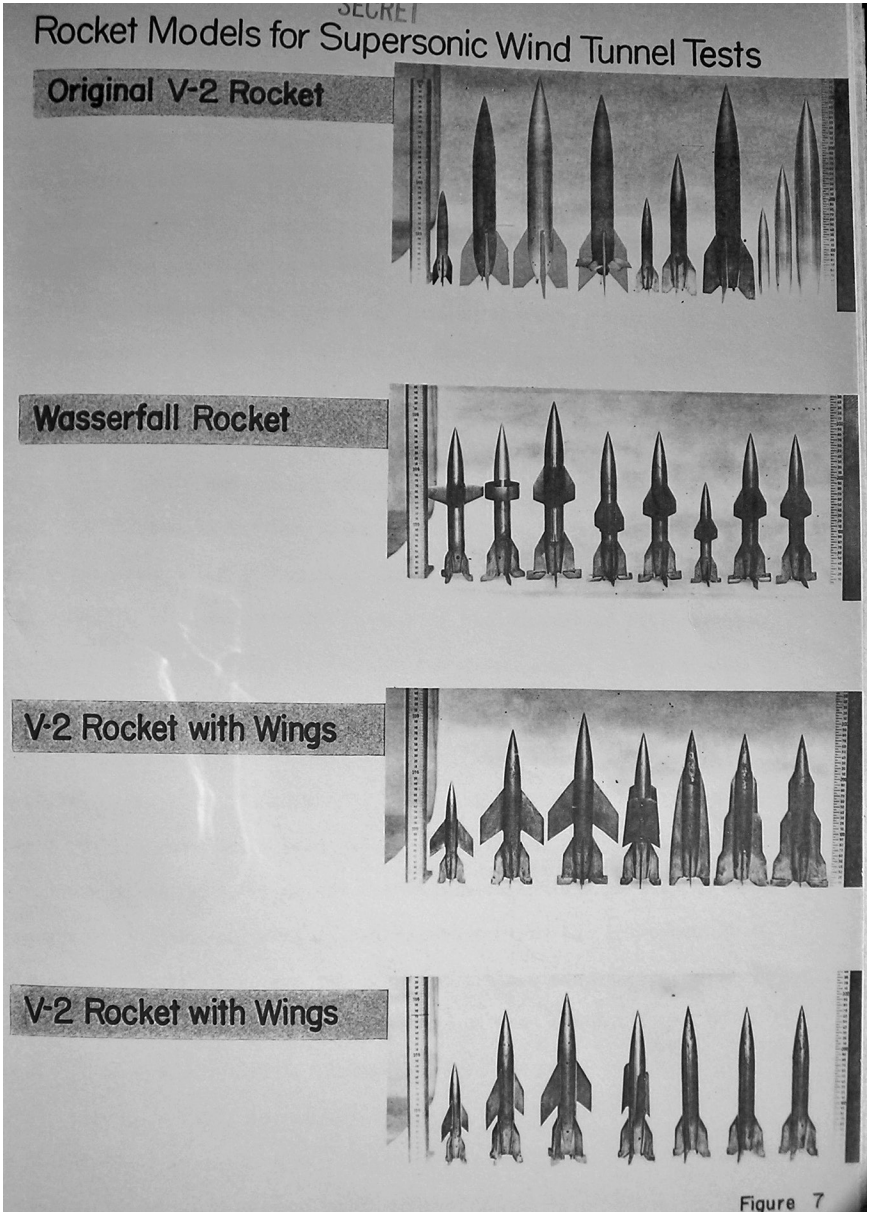
run the institute through much of the 1920s. Despite the excellence of his work and his growing fame, von Kármán was a Jew whose career and safety came under increasing scrutiny owing to growing anti-Semitism in Germany. In 1929, he agreed to move to the California Institute of Technology, where his research established Caltech as a force in the world of aeronautics. His European background made him uniquely qualified to assess the state of aviation and rocketry in Germany at the end of World War II.[20]

Just as the war was winding down in May and June 1945, von Kármán and his staff toured Germany, western Europe, and Soviet Russia in search of information on wartime advances in aviation technology. Von Kármán's group issued its preliminary report, *Where We Stand,* based in part on the findings from its European travels, on August 22, 1945. *Where We Stand* contained extensive

discussions of rocket engines of various kinds, jet engines and jet aircraft, radar, advances in aerodynamics, and nuclear jet propulsion. In the section covering rocket missiles, von Kármán was clearly impressed with the German rocket team's designs for a winged version of the V-2 that could carry a warhead across the Atlantic Ocean. "Perhaps the most important result of the German effort in this [missile] field was to show that winged missiles are superior in performance to finned missiles. Thus the next stage in the development of the V-2 rocket was to have been the addition of wings," he wrote, adding that many German rocket experts foresaw that "the ultimate guided missile would be completely automatic in its operation." The report included an illustration of fourteen winged variants of the V-2 rocket and eight versions of the Wasserfall antiaircraft rocket. Von Kármán added that the Scientific Advisory Group "agrees that the German results of wind tunnel tests, ballistic computations, and experience with V-2 justify the conclusion that a transoceanic rocket can be produced." The report contained an illustration of a "6000-Mile Rocket" resembling a V-2 flying from the United States to Japan, and stated that the accomplishments of the German rocket group and the development of the atomic bomb meant that all the air force's existing plans for future conflicts must be reconsidered.[21]

"A part, if not all, of the functions of the manned strategic bomber in destroying the key industries, the communication and transportation systems, and military installations of ranges of from 1000 to 10,000 miles will be taken over by the pilotless aircraft of extreme velocity," the report predicted. "For the future long-range strategic bomber, the Scientific Advisory Group foresees two types of pilotless aircraft, both with wings; one with a high trajectory reaching far into the outer atmosphere, and the other designed for level flight at high altitudes. The first one can be considered a further development of the V-2 rocket. In fact, this was planned by the German scientists."[22]

This rocket would use fins like those on the V-2 for steering, but it could also have larger wings to bounce off the lower atmosphere and glide toward a target, according to the report. "The second future strategic bomber is a supersonic pilotless aircraft, flying at altitudes of from 20,000 to 40,000 feet." This vehicle would fly at twice the speed of sound and could be preceded by an intermediate vehicle flying just below the speed of sound.[23] This report also pointed the air force toward long-range missiles using wings rather than ballistic missiles flying above the atmosphere. Historians have criticized the air force for



Rocket illustration from the Dryden study in *Toward New Horizons*. US National Archives

giving priority to winged missiles over ballistic missiles in the late 1940s owing to its preference for vehicles that resembled aircraft, but the air force in this case was also following the expert advice it got from von Kármán and his group.[24]

Toward New Horizons

The Scientific Advisory Group delivered its final report, *Toward New Horizons,* to Gen. Arnold on December 15, 1945. The thirteen-volume report contained von Kármán's introduction, along with *Where We Stand* and thirty other monographs on specific research topics by twenty-five authors. The whole report was shown only to members of the Air Staff and USAAF research staff at Wright Field in Dayton, Ohio, and was classified for many years. In his covering letter for the report, von Kármán called for a "global strategy for the application of novel equipment and methods, especially pilotless aircraft," and for "experimental pilotless aircraft units" to operate these new vehicles. In his introductory report, *Science: The Key to Air Supremacy*, von Kármán outlined research problems that he believed the air force should deal with, such as propulsion, aerodynamics, and weapons targeting. This section suggested that using liquid hydrogen as a fuel for rockets would open the door to high-altitude "rocket navigation" and satellites. In another section on organization of research, von Kármán called for the establishment of a permanent scientific advisory group for the USAAF commanding general; research panels for coordination of research with government agencies and other institutions; and the wide use of universities, research laboratories, and scientists outside the air force and military so that the military would not have to rely on a single source of information. It also recommended the establishment of a government "Center for Supersonic and Pilotless Aircraft Development" for research and development in this field, including wind tunnels and facilities for propulsion, control, and electronics research.[25]

The thirty technical reports in *Toward New Horizons* placed as much if not more emphasis on the technologies of piloted aircraft than on guided missiles.[26] Hugh L. Dryden from the National Bureau of Standards, who was soon to become the director of the National Advisory Committee for Aeronautics and, in the future, deputy administrator of NASA, the National Aeronautics and Space Administration, wrote the technical report on the "Present State of the Guided Missile Art." Dryden began in dramatic fashion with his prediction that the military's experience with tactical missiles in World War II "indicate that

another war will probably be opened by the descent in large numbers of missiles launched from distances perhaps of the order of 1000 to 6000 miles on an unsuspecting and unprepared country." Dryden used similar terms to describe the level of military interest in missiles, noting that "almost frantic efforts are being made to compress within a few months developments which ordinarily take years." But he warned that until more research and testing was done to determine the utility of various kinds of guided missiles, "there will be much confusion as to the military requirements which should be set forth." Unlike von Kármán in *Where We Stand*, Dryden did not indicate a preference either way on the use of wings with pilotless aircraft for long-range missions.[27]

While many research problems were obvious, Dryden explained, experience with missiles had shown "other problems not so easily foreseen." He listed five research problems: aerodynamics, power plants and propulsion, autopilots and servomechanisms, intelligence devices, and systems coordination. Research in these areas "will have to be extended far beyond the boundaries of information now available." He did not mention the problem of reentry heating for rocket warheads, which later became a major issue for long-range missiles, likely because it was covered in another technical report in the larger study. Dryden identified guidance as a key problem standing in the way of long-range guided missiles coming into wide use. German missiles such as the V-1 and V-2 carried autopilots, he wrote, but their accuracy was "not high," with the V-1 being able to strike within 5 miles of a target at a range of 130 miles, one out of two times, and the V-2 being able to strike within 10 miles at a range of 200 miles. Despite this low accuracy, he estimated that "considerable military damage has been produced." Listing conventional guidance ideas such as using television, radar, heat, or acoustic data to help direct missiles to targets, Dryden tacitly admitted the serious obstacles to improving their accuracy by also discussing the Japanese use of suicide pilots and even the possibility of utilizing animals as "intelligence devices" to direct missiles. Through his work in the National Defense Research Council during the war, Dryden was aware of psychologist B. F. Skinner's wartime work building a missile guidance system that used pigeons trained in pecking behavior to point to targets in what was known as Project Pigeon. The idea never got beyond testing and Dryden's mention of it in his report on rockets.[28]

The impact of *Toward New Horizons* on long-range missile research was discussed by Gen. Alden Crawford of the Air Staff in September 1945, after *Where We Stand* and before the final report, when he noted that the Germans found

these missiles promising, as proven by their work on the transatlantic A-9 and A-10 missiles, and that the USAAF's own scientific advisory group "also considers that this development field should be thoroughly explored and exploited."[29] The USAAF Air Materiel Command, which was responsible for the air force's research and development work for new weapons, drew up a five-year research and development program in the first months after the war, based on the findings of *Toward New Horizons*. A major part of this program envisioned the development of new guided missiles, and it also called for the air force to use private agencies wherever possible to carry out the air force's research and development work.[30]

Other Technologies

In *Science: The Key to Air Supremacy*, von Kármán wrote that the ramjet was the "logical power plant for supersonic flight with speeds greater than twice the speed of sound,"[31] and soon the USAAF had joined the army in looking at the possibilities of ramjets. In 1946, the air force began ramjet research with a missile called the X-7, which made its first flight in 1951. In 1950, the USAF began developing a ramjet-powered missile called Bomarc that was designed to intercept bomber aircraft. Despite their limitations, which became apparent early in their development process, Bomarc missiles stood on alert in the United States and Canada from 1959 to 1972.[32]

The USAF's Navaho winged missile, which had begun in 1945 along with many other air force missile projects, evolved in the late 1940s into a two-stage long-range vehicle, the first stage powered by rockets and the second stage by ramjets. Ironically, ramjets were added to Navaho just as the military's interest in ramjets was beginning to wane. By 1950, the air force was realizing that ramjets would not be as easy to build and operate as it had previously hoped. And ramjets were losing their edge over turbojets. In the late 1940s, turbojets could not fly faster than the speed of sound, but starting in 1950, technical innovations made possible turbojets that could fly at twice or three times the speed of sound. In the early 1950s, the creation of antiaircraft missiles meant that no aircraft was as safe as it had been when it needed only to outrun other aircraft in dogfights. As a result, the military need for aircraft that could fly two or three times the speed of sound nearly disappeared, except for specialized aircraft like the SR-71 reconnaissance aircraft. Existing ramjets were not useful without extra stages, as in Navaho and Bomarc, which both used booster

rockets, and so this technology fell by the wayside, although smaller missiles using ramjets have come into service in various nations.[33]

The concept of nuclear propulsion for aircraft and missiles was probably more prominent than ramjets in 1945, but it wound up never coming close to regular use. In *Where We Stand*, von Kármán found nuclear power to be a worthwhile source of power for aircraft because the fuel would not be a major weight factor, and if the weight of other parts of the propulsion system could be reduced, nuclear power could be used to power aircraft almost "without range limitations." Despite many unresolved technical problems, he said that research in this area deserved the air force's "immediate attention." In *Science: The Key to Air Supremacy*, von Kármán acknowledged that radiation issues would limit the usefulness of nuclear propulsion in crewed aircraft, but this form of propulsion would still be useful in pilotless aircraft. He also proposed the establishment of a "Center for Nuclear Aircraft Development."[34]

The Finletter Report on Air Power in 1948 said the "possibility of employing atomic energy for the propulsion of aircraft and guided missiles is sufficiently important to warrant vigorous action" by the Atomic Energy Commission (AEC), the USAF, the navy, and the National Advisory Committee for Aeronautics. The report urged that work underway by the USAF and the AEC under the Nuclear Energy for the Propulsion of Aircraft program be "intensified." In a memo assessing the relative utility of long-range missiles and bombers, air force Maj. Gen. Earle E. Partridge wrote that "developments in nuclear propulsion may have a great effect upon the situation."[35]

Although the idea of nuclear propulsion ultimately had little direct bearing on missile programs, its existence caused some air force decision makers in the late 1940s to see a future for long-range nuclear bombers and missiles before the failings of the concept—such as radiation exposure to aircrews and the dangers presented by crashes spreading radiation—caused it to lose popularity. The air force and the AEC replaced the Nuclear Energy for Propulsion of Aircraft project in 1951 with an expanded program, the Aircraft Nuclear Propulsion program. In 1955 and 1956, a single modified B-36 bomber flew with a nuclear reactor on board to test radiation shielding for aircrews. The program, which continued until the Kennedy administration officially ended it in 1961, cost an estimated $10 billion in 2016 dollars. The air force also considered the possibility of nuclear-powered ramjets, but the air force did not begin active work on the idea until 1957, when it and the AEC began Project

Pluto. Its cancellation in 1964 brought to a finish the major dead-end research effort coming out of *Toward New Horizons*.[36]

Historian of technology George Basalla has cited nuclear-powered aircraft along with nuclear-powered spacecraft and cargo ships as prime examples of a technological fad, in this case generated by the 1940s and 1950s enthusiasm for nuclear energy that he compared to the nineteenth-century fad for railways and the early twentieth-century enthusiasm for aviation, when many experts predicted that every family would own and use personal aircraft. In the late 1940s, many experts saw nuclear propulsion for aircraft and missiles to be just as promising as the idea of long-range ballistic missiles. But nuclear propulsion proved to have many serious drawbacks.[37] After some time and not without difficulty, rocket technology for long-range missiles began to advance where nuclear technology had failed and ramjets were faltering.

Official air force histories praise *Toward New Horizons* and quote the plaudits given by Arnold and others who were cleared to read it. Many of its recommendations were carried out, including the creation of a permanent scientific advisory board for the air force, headed in its early years by von Kármán, and the creation of the air force's Arnold Engineering Development Center in Tennessee. But the report also pointed to some technological blind alleys such as nuclear propulsion.[38]

A Contest with Consequences

As outlined above, the army, navy, and air force were all working on new missile programs as World War II came to an end. Although the future place of missiles was not clear in the first few years after the war, the German V-1 and V-2 missiles showed potential that could not be ignored, especially with talk of combining missiles with nuclear weapons. In addition to developing plans for missiles, the USAAF decided to lobby hard to control US military missile programs, while Army Ordnance, with support from the navy, resisted the USAAF quest for control. The USAAF's existence as a branch of the US Army complicated the question of jurisdiction over missiles during the war and until the air force won its independence in 1947. Prior to that time, the contest for control of missiles took place inside the War Department, which controlled the army and its branches until 1947, and after that time, the contest between the new US Air Force and the US Army moved to a new arena.

The consequences of the battle for missiles had implications that went well beyond the simple question of which service had control of them. Because the

air force viewed missiles as aircraft and the army saw them as a form of artillery, the results of the competition between the two services influenced the design, capabilities, and evolution of America's ICBMs and also its space launch vehicles. Aircraft design puts a premium on lightweight streamlined design, while cannons and other artillery pieces are designed with durability more in mind. The army missile team, which included many of the German rocket experts who built the V-2, used different management techniques and technical designs than the USAF did to build rockets. For example, the army had a tradition of in-house development and production under its arsenal system, while the air force generally used private contractors to develop equipment such as aircraft and missiles.[39]

In addition, the air force already controlled what was then America's only means of delivering nuclear weapons to its adversaries—crewed bomber aircraft—while the army had no involvement with nuclear weapons in the postwar years. The air force and its contractors formed a distinct management structure that developed new weapons in a decidedly different manner from that of Army Ordnance.[40] Von Braun and his team developed a reputation of being conservative in their use of technology both at Army Ordnance and later on in the 1960s when they built the Saturn rockets in the Apollo program, while Convair, the air force contractor that built the Atlas ICBM, developed cutting-edge concepts for Atlas, such as the rocket's thin-skinned fuel tanks.[41] For reasons of approach, background, and style, America's first ICBM would have taken a different form from the Atlas missile that the air force created if the job had gone to Army Ordnance rather than the air force.

If outside precedents carried any weight in this matter, control of long-range US missiles might have been handed to Army Ordnance. In Nazi Germany, the Luftwaffe supervised the development of the V-1, while Wernher von Braun's team developed the V-2 rocket under the auspices of German Army Ordnance. In the Soviet Union, Stalin's Council of Ministers placed missile development under the artillery branch of the Red Army, although the aviation industry was also heavily involved in developing missiles.[42]

The Contest Is Joined

During the contest between the three American services for control of long-range missiles in the late 1940s, the main combatants were the air force and Army Ordnance, although the navy also stood alongside the army against the air force. All three services had begun missile programs during World War II,

and their contest for control of missile programs, including long-range missiles that eventually would become known as intercontinental ballistic missiles, dates from that time. The contest for control of missiles began in earnest in the fall of 1944, when Army Chief of Staff Gen. George Marshall decided on how to divide missile programs between Army Ordnance and the USAAF, at least for the short term. A directive issued on October 2 over the signature of Marshall's deputy chief of staff, Lt. Gen. Joseph T. McNarney, gave the USAAF responsibility for all guided missiles "dropped or launched from aircraft," or "launched from the ground which depend for sustenance primarily on the lift of aerodynamic forces." Army Ordnance was assigned ground-launched missiles that reached their targets purely on their own thrust and not using wings. The McNarney directive, as the ruling came to be known, was silent on who would gain operational control of missiles once they were developed. It was an ambiguous document that was clearly a compromise between the army's contending services.[43]

The air force leadership worked to protect the USAAF's interests in the field of missiles by trying to overturn the McNarney directive, and it looked out for what it saw as transgressions of the directive by Army Ordnance and even the navy, which wasn't covered by the directive. In January 1945, the USAAF won the right to deploy the JB-2 missile, the American version of the V-1, because the USAAF had developed the JB-2.[44] There the matter stood as the war officially ended with the formal Japanese surrender on September 2 and as Army Ordnance proceeded with importing parts and plans for V-2s and skilled German rocket engineers.

When Gen. Dwight D. Eisenhower succeeded Marshall as army chief of staff in November 1945, the USAAF lobbied him to win control of missile research. Eisenhower played a key role in the development of US military missiles as army chief of staff to February 1948, and later from 1953 to 1961 as president of the United States. He had risen to prominence during World War II when he was appointed as supreme commander of Allied forces in North Africa and then the Mediterranean before being given command of the Allied invasion of western Europe that began in France in June 1944. Eisenhower continued as supreme commander of the Allied forces in Europe through the end of the war. During that time, he had to deal with the threats posed by the German V-1 and V-2 missiles, which had caused him concern because of their effects on military and civilian morale. When he became the postwar army chief of staff,

Eisenhower had to look out for the competing interests of both the USAAF and Army Ordnance, and keep in mind the interests of the US Navy.[45]

The Air Staff—which supported the USAAF's commanding general and later the air force chief of staff—chafed at the openings the McNarney directive gave to the other services, and it directed bureaucratic resistance to the directive and to missile programs conducted by the other services. It interpreted the directive to widen the USAAF's jurisdiction to include virtually every guided missile produced by the US military. The USAAF's interpretation of the McNarney directive also reinforced its own view of missiles as a form of aircraft. Brig. Gen. Alden R. Crawford and other Air Staff officers similarly argued that all types of aircraft, including missiles, need wings to turn and to glide, and that the air force must win control of all missile programs to avoid duplication of cost and effort.[46] The air force tried to "discourage the other services from encroaching on Air Force missions and roles" by using the term "pilotless aircraft" instead of "guided missile," although at times the former denoted a particular type of the latter.[47]

While members of the Air Staff were lobbying to win control of guided missiles, not everyone in the air force shared their interest in guided missiles. As part of his drive to orient the air force toward new technologies, Arnold had appointed Maj. Gen. Curtis LeMay in December 1945 as the deputy chief of Air Staff responsible for research and development. But Arnold soon retired, and LeMay was reluctant during the nearly two years he held the research and development post to exercise the limited planning authority that had been contemplated for his position.[48] In common with most other American military and political leaders of the time, LeMay saw missiles first as a defensive rather than a strategic weapon. "We in the air force are assuming that guided missiles will be fired at bombing vehicles whatever their form may take and are already taking measures to develop and destroy enemy vehicles whether they are fighter planes or guided missiles," he wrote the assistant secretary of war for air in May 1946.[49] The commander of the Air Materiel Command, which had responsibility for guided missiles, Lt. Gen. Nathan F. Twining, proposed that the USAAF agree to give Army Ordnance control of antiaircraft missiles, along with what he called the "V-2 type of Ground-to-Ground projectile," the type of missile that would include ICBMs.[50] A few months earlier, Gen. Crawford in the Air Staff complained that the command's leaders considered guided missiles to be merely "'Buck Rogers' gadgets."[51]

Despite the differing viewpoints on missiles inside the air force, the Air Staff's effort to gain control of these new weapons won a minor victory when the office of the army deputy chief of staff announced in February 1946 that it would review the McNarney directive.[52] When representatives of the USAAF and Army Ordnance met on March 25 at LeMay's suggestion to resolve their differences over responsibilities for guided missile work, agreement proved impossible when both Army Ordnance and the USAAF refused to move from their divergent positions on who should control missiles with wings.[53] In May, the USAAF made its case to Eisenhower for assignment of guided missiles to the USAAF, pointing to its Strategic Air Command as the repository of expertise for strategic missiles. "It is inconceivable that two agencies, one with piloted bombers and the other with pilotless aircraft, could do this independently, both must be under one commander," a USAAF memo added.[54]

In June 1946, Eisenhower named Maj. Gen. Henry S. Aurand, an Army Ordnance officer, as the War Department's director of research and development.[55] When the USAAF briefed Aurand the following month on its missile programs, it had to admit that Army Ordnance had given its rocket programs 1A priority, while the USAAF gave its guided missile programs a lower 1B priority.[56] This admission exposed the USAAF's incertitude about missiles, but the air force continued pressing to control them. After the USAAF and Army Ordnance tried and failed to solve the disagreement on their own for a second time, Aurand tried in September to solve the missile standoff with a proposal where Army Ordnance and the USAAF would share missile responsibility with War Department staff coordinating the work.[57] Given Aurand's background and reports that he was critical of the air force's quest to control missiles, the USAAF was learning that it would not likely win acceptance for its plan to control missile programs by working inside the War Department.[58]

By then, the dispute over missiles had become public knowledge as newspaper articles speculated about control of military guided missile programs and reported that outside parties wanted the dispute settled. *New York Times* military writer Hanson W. Baldwin wrote in May 1946 that the Army Air Forces were engaged in a "frank and outspoken" effort to gain control of military long-range missiles, with Army Ordnance united with the US Navy in opposition to the air force's plans.[59] On August 19, 1946, a *Washington Post* article revealed that the War Department was reviewing USAAF and ordnance missile contracts after a "series of protests by civilian manufacturers and scientists, who charged that the two service branches were competing for materials in their

race for control of guided missile development." The story quoted army sources as saying that no solution was likely "until and unless President Truman intervenes personally."[60]

The increasing visibility of the controversy caused top officials of the War Department to enter the missile dispute and try to bring it to an end. Lt. Gen. Thomas T. Handy, who had succeeded McNarney as deputy chief of staff, told Eisenhower that "industrialists" were complaining that "there is great duplication and actual waste of money, [and] that they are being asked to accomplish practically the same projects for several agencies" at a time when facilities and personnel were available for only one job each.[61] Handy said these leaders "all agreed that the most practicable solution is the assignment of the responsibility to one agency, and that this agency should be the Air Force," although the ordnance chief agreed only reluctantly.[62]

A new missile directive replacing the McNarney directive was released on October 7, 1946, over the signature of Brig. Gen. Henry I. Hodes, the assistant deputy chief of staff. The new directive gave the USAAF's commanding general responsibility for "research and development activities pertaining to guided missiles," including countermeasures and all associated equipment. The directive called for use of the best-qualified agencies for missile work. It also gave the War Department's director of research and development, Gen. Aurand, a role in determining missile projects.[63] Three days later, Aurand issued his own directive, which emphasized that the directive from Hodes was for research and development only and was not to be seen as granting any operational responsibility for guided missiles.[64] W. Stuart Symington, the assistant secretary of war for the air force, released the new missile directive to the media, calling it one of the most important national defense decisions ever because it would save millions of dollars by avoiding duplication of effort. In his own press statement, LeMay, the air force's top officer for research and development, explained that, starting with fiscal year 1949, all budget estimates for missile programs would go through the USAAF. LeMay stressed that the new directive would save money but warned that research and development of new missiles would be a lengthy process.[65]

During the two years between the end of the war and the reorganization of the US military, the USAAF also kept a wary eye on the navy's missile programs, since the relationship between the navy and the air force was strained as leaders of the two services differed over military unification and nuclear doctrine. Baldwin's *New York Times* article on the interservice missile dispute

reported that the navy and Army Ordnance had worked together to head off the USAAF's ambitions to take over military missile programs, and quoted a USAAF officer as saying that the arrival of atomic bombs and rockets meant that the navy was "finished."[66] Rear Admiral Daniel V. Gallery, who ran the navy's missile program, was quoted by the USAAF as saying that the Navy Department was reluctant to agree with the air force on specifications for a missile because of its fear that "once a common set was accepted, the AAF would use this as an argument to take over all of the national guided missile development program."[67]

The USAF Keeps Up the Fight for Missiles

The October 1946 arrangement between the USAAF and Army Ordnance for guided missile research and development continued until shortly after the US Air Force won its independence from the army.[68] The War Department approved a missile plan from USAAF Commanding General Spaatz and published it on November 26, 1946. The plan designated the USAAF Technical Committee to direct War Department guided missile projects, with appeals going to Aurand, but the committee was seldom called upon to settle disputes between the services.[69] When the USAF began its separate existence on September 18, 1947, it signed an agreement with the army on division of responsibilities that granted operational responsibility for short-range tactical missiles to the army, divided control of the contentious group of antiaircraft missiles between the army and air force, and awarded operational control of strategic missiles to the USAF. The vaguely worded agreement defined strategic missiles as those designed for use against targets that are normally reached by bombers and that did not affect army combat operations. These missiles included what would become known as ICBMs. The deal reflected the realities on the ground, where both services were actively developing antiaircraft missiles and had yet to give serious thought to long-range strategic missiles.[70] In March 1948, nearly six months after the USAF won its independence, it agreed with Army Ordnance to rescind the 1946 War Department missiles directive and return responsibility to the army for research and development on missiles then being developed by the Ordnance Department.[71]

The navy continued to delay its response to air force calls to agree on missile requirements even as the air force won its independence from the army.[72] Tensions escalated in December 1947 as Adm. Gallery called for "an aggressive campaign aimed at proving that the Navy can deliver the Atomic Bomb more

effectively than the Air Force can," which would have left the air force responsible only for air defense. Superior officers in the navy rejected his idea of naval control of all nuclear weapons because they opposed the idea of one service having exclusive control of these weapons.[73]

As the USAF won its autonomy, LeMay was transferred to head up air forces in Europe as Cold War tensions increased there, and the following year he was moved again to lead the Strategic Air Command. The research and development post in the Air Staff that LeMay had held for nearly two years was eliminated, and research and development was put under the control of a lower level officer inside the Air Materiel Command.[74]

Conclusion

The creation of the US Air Force did not end its contest with the army and navy for control of guided missiles, and the 1947 and 1948 agreements it signed with the army meant only a pause in these hostilities. The War and Navy Departments had given way to three service departments nominally working under the supervision of what proved to be a weak National Military Establishment headed by the secretary of defense and the Joint Chiefs of Staff. The army and navy held on to their roles in defending against attacking aircraft through programs such as the army's Nike antiaircraft missile. The interservice disputes over missiles was about to move to new arenas.

While Theodor von Kármán and Hap Arnold had challenged the air force to look to missiles in its future, Hugh Dryden's technical report and other studies contained in *Toward New Horizons* summarized the serious technical problems that needed to be overcome before long-range missiles could compete with bombers like the B-29. The work of Dryden and von Kármán showed that winged rockets and missiles using exotic technologies such as ramjets and nuclear propulsion were under consideration in addition to ballistic rocket missiles. And while the air force was trying to seize control of missiles, especially long-range offensive missiles, there was evidence that not all air force leaders supported this work. If the air force wasn't ready to build missiles, Army Ordnance with its team of German rocket engineers was also working on missiles of its own.

4 Tentative Steps on Rockets

The leaders of the US Army Air Forces knew that to win control of missiles in the US military in the postwar world, it would have to develop missiles of its own. As it canceled its few wartime missile programs, including its reverse-engineered version of the V-1, the USAAF embarked in the months following World War II on a whole new set of ambitious missile programs to fulfill all the missions the air force might face in the years to come.[1] Reports such as *Toward New Horizons* were helpful for newcomers to this emerging field, but the work of actually designing, building, and testing new missiles was more important. While those reports pointed to competing propulsion technologies, the variety of missile programs the USAAF began in 1945 reflected the wide-open meaning of guided missiles at the time. Most of those missiles died on the drawing board under the pressure of postwar budget restraints, but one made it to the launch pad. The MX-774, which later became known as the link between the German V-2 ballistic missile and the sleek ICBMs developed by the US Air Force in the 1950s, flew only three times before it too was canceled. Missile programs such as the air force's Navaho and the navy's Viking continued as the 1940s drew to their end.

Meanwhile, in the Soviet Union, the government expressed interest in the V-2, but its long-range missile program took a back seat to bomber aircraft and nuclear weapons, two things the United States had and the Soviet Union lacked. When Soviet rocket experts were set to work on a long-range rocket missile, it was a replica of the V-2. In the end, both superpowers made only modest progress on rockets in the late 1940s.

The Meaning of Missiles

In the late 1940s, the term "guided missile" had a much different meaning than it does today. In recent years, a guided missile usually has suggested a rocket with a guidance system, but the definition of guided missile in the 1940s was much broader than that. In their most literal meaning, missiles encompass a

variety of objects, including rocks, spears, arrows, bullets, bombs, or rockets, projected or fired toward another object or target. Guided missiles can have their courses directed by an internal mechanism controlled by radio or television signals, target-seeking radars, or other devices, or through preset target information, as in torpedoes, bombs, aircraft, and rockets without human pilots. For example, the German V-1s and V-2s are remembered as the first long-range guided missiles put into military service, but they were far from being the first weapons to be called guided missiles.

The experience of the USAAF and its predecessor organizations with guided missiles dates back to 1917, when it began experiments with remote-controlled aircraft and bombs that continued through the interwar period. These programs proliferated during World War II, and air force historian Mary R. Self divided the USAAF's wartime missile projects into four groups, illustrating the wide variety of weapons that fit into the definition of guided missile at the time. The first group consisted of "various airplanes or airplane-like structures, powered conventionally, loaded with explosives, and remotely controlled into a target." The second group was made up of "glide bombs or glide torpedoes, which were air launched and guided to the target by various means." The third group was air-launched bombs controlled in range and direction from the launching aircraft, or by self-contained devices that sought out the target. And the fourth group included missiles similar to the V-1 winged jet missile.[2] In other words, most guided missiles at the time were either remote-controlled aircraft or bombs with some ability to control their paths. None of the guided missiles included in her definition were surface-to-surface rocket-propelled vehicles, like the V-2 long-range rocket or even an ICBM, which then was still in the future. Today most remote-controlled winged aircraft, including those propelled by jet engines, are known as drones. Those that deliver ordnance or a special payload to a target are known as cruise missiles.[3]

At war's end, the air force set out to promote itself to the public as the service that uses missiles, and it decided to use existing resources to carry out this job.[4] In January 1946, it decided to fly a demonstration model of a guided missile with a range longer than 3,000 miles before a deadline of August 1, 1946, "to impress upon the public that the Army Air Forces have, and can use immediately, some form of guided missile." The USAAF quickly fleshed out the idea into a concept using a B-29 aircraft under automatic control. This concept was nothing new—aircraft under automatic control, often bombers near the end of their service lives, were used during World War II as guided missiles. What

became known as Project Banshee grew with an enlarged goal of testing guidance equipment. But Banshee began to fall behind schedule as ground crews and contractors with limited resources dealt with the project's greater-than-expected complexity. Banshee was finally canceled in 1949 without ever having flown. The air force's first attempt to show mastery of guided missiles to the public had never got off the ground.[5]

A similar fate awaited the USAAF's first scheme to mate nuclear weapons to guided missiles, which got its start when top air force officers began considering the idea upon hearing the news of the atomic bomb striking Hiroshima. In testimony to Congress in October 1945, USAAF Commanding General Arnold mentioned the possibility of launching atomic bombs atop missiles, and by January 1946, the USAAF was actively studying the matter. A few weeks later, in March, the Air Materiel Command (AMC) began to solicit bids from industry for an atomic-capable missile called Mastiff. But the USAAF soon ran into resistance from the management of the Manhattan Project, which refused to share technical information about nuclear weapons without highly elaborate security measures that air force research officers deemed impractical. The Atomic Energy Commission, which took control of nuclear weapons and materials from the Manhattan Project in January 1947, was not any more amenable to sharing information, so shortly before the air force became an independent service in September 1947, Mastiff was quietly dropped. No new discussions about nuclear-armed missiles took place inside the air force until 1949.[6]

Soviet Rockets

At first glance, the Soviet Union moved more deliberately than the United States when it came to establishing a postwar rocket program. Such a program began on May 13, 1946, when Josef Stalin signed a ministerial decree establishing a high-level committee to oversee missile programs as part of a structure that appeared similar to that used for the Soviet nuclear weapons program.[7] But historian Asif Siddiqi explained that missile programs were far less important to Stalin and the top Soviet leadership than nuclear weapons or bomber aircraft. While Stalin met several times during these years with leading aviation designers like Tupolev and leaders of the nuclear weapons program, the Soviet leader met only once with Korolev, and Siddiqi noted that the high-level missile committee was dissolved in 1949. Unlike the United States but like Germany, ballistic missiles in the Soviet Union were put under the jurisdiction of the Red Army's Main Artillery Directorate, because the army, which had enjoyed suc-

cess with Katyusha rockets during the war, expressed a greater interest than the air force did in ballistic missiles. The main missile design bureaus were put under the Ministry of Armaments, which was also separate from the aviation industry. With the support of a powerful patron, Minister of Armaments Dmitri F. Ustinov, Sergei Korolev was put in charge of his own design bureau in the northern suburbs of Moscow.[8]

At Korolev's sole meeting with Stalin, which took place in April 1947, the dictator questioned the rocket designer about the relative merits of rockets and bomber aircraft, reflecting Stalin's interest in the latter. Stalin had set Tupolev to work in 1943 on designing a bomber aircraft after the Americans rejected requests to send the Soviets bomber aircraft through the Lend-Lease Program that the United States had set up to supply badly needed arms and equipment to wartime allies such as Britain and the Soviet Union. Stalin had hoped to get America's most advanced bomber, the Boeing B-29 Superfortress. In the last half of 1944, three B-29s made emergency landings in the Soviet Union after bombing raids on Japan, and a fourth crashed in Soviet territory. Stalin refused to return the B-29s and ordered Tupolev to create a Soviet replica of the aircraft, which was far more advanced than any Soviet aircraft at the time. Stalin's orders were so strictly enforced by his notorious secret police chief Lavrenti Beria that Tupolev was only half joking when he asked if the replica, known as the Tu-4, should have Soviet rather than American markings.[9]

Like the B-29, the early Tu-4s had development problems, and the Tu-4 did not enter service until 1949. The Tu-4's limited range allowed it to reach only the western United States on a one-way flight from the Soviet Union, and only after passing over Alaska and Canada. Unhappy with the state of Soviet jet technology in 1951, Tupolev refused to attempt to build a jet bomber with the required range to attack the United States. Stalin gave the job to the design bureau of Vladimir M. Myasischev and provided Myasischev with lavish resources to do the job. Myasischev's long-range jet bomber still fell short of the range requirements for round-trip flights to the American mainland, and it was only built in limited numbers. Tupolev's bureau began work in 1950 on a long-range bomber with turboprop engines, the Tu-95, known in the West as the Bear. The aircraft first flew in 1952 and entered service four years later. Despite its limitations, the Tu-95 remains the mainstay of the Russian long-range bomber force to the present day. Steven Zaloga, an authority on Russian forces, wrote that American intelligence exaggerated the threat from Soviet bombers, creating the "bomber gap" controversy in US politics in 1955 and sparking massive

American spending on antiaircraft missiles and radars in Alaska, Canada, Greenland, and the northern US states to defend against Soviet bombers. Only when the U-2 reconnaissance aircraft began overflying the Soviet Union in 1956 did American leaders learn the true dimensions of the Soviet bomber threat.[10]

Just like he wanted the B-29 copied, Stalin also ordered Korolev to replicate the German V-2 ballistic missile. After copying the V-2 as the R-1 rocket, Korolev's design bureau proceeded in 1948 with the R-2, an uprated R-1 with a range of 375 miles, and then with three new rockets—a tactical missile known as the R-11 to replace the R-2 with easier-to-handle fuels, and two medium-range missiles to strike targets in Europe and Japan, including forward deployed American forces. The R-3 had a range of 1,800 miles, and the R-5 a range of 1,750 miles. The R-11 tactical missile gained fame later as the Scud missile, which was adopted by other countries, most famously Iraq during the first Gulf War in 1991. Korolev's design and technical studies in 1951 and 1952 for the R-3, whose range was still far short of an ICBM but promised a major increase in range over the R-2, also looked at the technologies that would be needed for missiles of an intercontinental range. The R-3 quickly ran into problems that slowed the program, as rocket engine designers struggled to overcome problems with the new engines that would be needed for the missile.[11] The Soviet Union did little with missiles in the first years after World War II.

Roots of the MX-774

When the war ended, the US Army Air Forces did not attempt to replicate the V-2 as the Soviets did or as it had done with V-1 in the final months of the war. Nor did the air force hire German rocket experts as a group, as Army Ordnance did with the von Braun group, although some of them consulted with air force research staff at Wright Field in Dayton, Ohio. Hiring large numbers of experts from Germany or elsewhere and forming an in-house development group would have gone against the air force tradition of procuring aircraft from private contractors, a tradition that went back to 1908, when the US Army purchased its first aircraft from the Wright brothers. As the army's air arm grew into the USAAF, it continued to procure its aircraft from outside contractors, which set it apart from the army's tradition of developing weapons in-house through the arsenal system. By 1947, an estimated 85 percent of the air force's research and development budget was spent in private industry.[12]

The air force formally began its postwar missile program in August 1945 when USAAF headquarters published military characteristics—the physical and

operational specifications it sought—for several types of air defense as well as for tactical and strategic missiles. These included ground-to-ground missiles classified as having short ranges, between 175 and 500 miles, medium-range missiles between 500 and 1,500 miles, and long-range missiles between 1,500 and 5,000 miles.[13] In October, the USAAF invited seventeen aircraft contractors to submit proposals for ground-to-ground missiles of various ranges, and eleven responded. In February 1946, the USAAF selected two pairs of proposals for each of the three ranges, including bids from Consolidated Vultee Aircraft Corporation and Northrop Aircraft to study long-range missiles. Consolidated Vultee's proposal included a winged, subsonic jet-powered missile and a rocket-powered ballistic missile sometimes known as Hiroc under project number MX-774. In project MX-775, Northrop began developing two winged missiles, a subsonic turbojet missile known as Snark and a supersonic version known as Boojum. At the same time, North American Aviation won a study contract under project MX-770 to begin work on a short-range winged rocket that later became known as Navaho. At that point, the USAAF and its contractors were working on twenty-eight missile programs. Although these contracts appeared to cover all possible defensive and offensive purposes the USAAF might have for missiles, a few categories of missiles were missing, including very short-range missiles, which were under negotiation with the Army Ground Forces, and missiles with ranges greater than 5,000 miles, because air force leaders felt that advances in missile design needed to be made on shorter-range vehicles before such long-range missiles could enter serious development.[14]

Like other aircraft contractors of the time, Consolidated Vultee, also known as Convair, was motivated to bid on the missile work because its wartime aircraft work had ended with World War II. Convair had built thousands of aircraft during the war, notably the B-24 bomber, but unlike most other contractors at war's end, it had a major new contract building the B-36 long-range bomber for the air force. Convair's Vultee division in Downey, California, also had rocket experience from wartime in the form of the Lark antiaircraft missile built for the navy. Under Project MX-774, Convair won a contract from the USAAF for $1.4 million to spend per year studying its two concepts for long-range missiles.[15]

As the first year of the contract period drew to a close, what became known as the "black Christmas of 1946" followed word that the Bureau of the Budget was cutting the air force's $186 million in research and development funds for fiscal year 1947 by $75 million. For missiles, that meant that more than half

the budget was gone—from $29 million to $13 million. By the following March, the Air Materiel Command had canceled eleven of the air force's twenty-eight missile programs and added one. Among the casualties was the winged jet-engine version of MX-774, leaving only the ballistic missile version. Northrop's Boojum and Snark were folded into one jet-propelled winged missile under the Snark name, and only after Northrop president Jack Northrop lobbied aggressively to save the program. While Convair was free to concentrate on the one ballistic missile, it learned that the money it had received for one year would have to last for two. The tight money policy followed the 1946 congressional elections, when Republicans had won control of both the House and Senate, bringing with them plans to cut budgets and taxes. In the early months of 1947, the USAAF became aware that President Truman and the new Congress would cut USAAF research funding again for fiscal year 1948. In response, the air force placed a higher priority on projects likely to provide an immediate payoff in new or improved weapons. Missile research funds were set at $22 million, which at first appeared to be an increase from the final figure for 1947 but in fact led to further cuts to projects that were moving from the drawing board to fabrication.[16]

Maj. Gen. Benjamin W. Chidlaw, the Air Materiel Command's deputy commander for engineering, ordered a further reduction in USAAF missile programs from seventeen to twelve on May 6, 1947. He called the individual programs all "desirable and technically sound," but the missile program as a whole was "considerably overexpanded" for the available budget of $22 million, and therefore must be drastically cut. Chidlaw called for elimination of "insurance missiles" such as subsonic missiles performing the same mission as supersonic missiles. "Also eliminated is the 5000-mile range [MX-774] rocket which does not promise any tangible results in the next 8 to 10 years," he ordered, and instead missiles that show the promise of "early tactical availability" would get top priority. In his list of missiles being continued, Chidlaw included a North American Aviation study of a 5,000-mile-range supersonic missile, but he predicted it would likely take the novel form of a "nuclear energy ram jet." At the time, North American was building a shorter-range winged rocket under the MX-770 program, and Chidlaw's order became a stepping stone toward that program becoming the Navaho long-range missile. But the nuclear ram jet idea never became part of MX-770.[17]

A detailed Air Staff report attached to Chidlaw's order stated that the air force should not spend money on the development of a 5,000-mile rocket for two

Launch of an MX-774 (RTV-A-2) rocket at White Sands, New Mexico, possibly 1948. Note the telemetry leads still attached to the vehicle as it leaves the launch pad. Smithsonian National Air and Space Museum (NASM 83-294)

reasons. First, the MX-774 was fueled with alcohol, whose power was "too low" for a long-distance missile. Further work on this rocket would need to wait until more powerful fuels were available. Second, little was known about materials that would allow warheads to survive the heat of reentry into the atmosphere, requiring what the report called a "long series of costly experiments."[18] Convair got an even more negative message from the air force when an official from the contractor went to Washington that spring to lobby for the MX-774. Military

scientists told him they believed that missiles with ranges longer than 3,000 miles were "at least twenty-five years in the future," and some air force leaders shared their belief "that air vehicles without cockpits didn't belong in the Air Force."[19]

By then, the Convair engineering team headed by Karel J. "Charlie" Bossart, a Belgian-born aeronautical engineer, had built the first of ten planned MX-774 rockets. The 9.6-meter-tall (31.4 feet) MX-774 was significantly smaller than the V-2 but contained important design improvements, most of them aimed at cutting the weight that limited the range and speed of rockets like the V-2. First, Bossart's team eliminated separate internal walls for fuel tanks and used the airframe itself to contain the fuel, cutting weight and increasing fuel capacity. As well, it removed stiffeners from the airframe and retained rigidity in the tanks by relying on the rocket's fuel or nitrogen gas under pressure when the rocket was not fueled. The team also designed the rocket to separate the warhead after the rocket engine stopped firing so that heat protection would not be needed for the rocket body. Bossart's team also designed gimbaled or swiveling engines to steer the rocket. This innovation took the place of the tilting vanes used in the V-2 and other early rockets to direct the rocket by deflecting the exhaust jet. While the MX-774 contained a conventional guidance system for the time, Convair engineers were building a more advanced radio guidance system known as Azusa.[20]

The air force canceled MX-774 on July 1, 1947, but it allowed Convair to use the remaining funds from its contract to test and launch three MX-774 rockets. After extensive ground testing in California, the three MX-774 rockets were launched at the White Sands Proving Ground on July 13, September 27, and December 3, 1948. All three fell well short of the planned altitude of 100 miles, with two exploding in the first minute of flight and the third reaching an altitude of only 10 miles. Convair reported that it came to understand the reason for every failure, and thus the flights proved the new features designed into the missile.[21]

As the Convair team prepared the third and final MX-774 rocket for launch, air force officers and Convair tried to save the program by proposing that the rocket be used for technical testing, as a tactical missile, to launch scientific payloads, and even to train launch crews. Convair made a formal proposal to the AMC in November 1948 to revive the MX-774 program by developing two tactical missiles with a range of 1,000 miles, one carrying a 3,000-lb warhead and another carrying a 6,000-lb warhead. While some internal air force

technical evaluations criticized the Convair proposal for being hastily put together, the Guided Missiles Branch stated its belief that Convair's arguments to continue with MX-774 were sound, and "that to neglect long-range rocket research is to close the door on our most promising avenue for improved missile performance."[22]

After Convair was verbally informed on February 16, 1949, of the USAF decision to reject the contractor's proposal to revive the MX-774 as a tactical missile, Lt. Col. Charles Terhune, then deputy chief of the air force's Guided Missiles Branch, explained that taking on the Convair proposal would mean the air force would have to cancel another missile program. He added that a number of technical problems would have to be solved before a long-range ballistic could become feasible, including warhead reentry at high speeds and guidance systems.[23]

The MX-774's supporters inside the USAF then tried to promote the MX-774 as a launch vehicle for scientific research packages for the upper atmosphere. Physicist Marcus O'Day, who led the air force's upper atmosphere research during the late 1940s, and other air force officials talked up the MX-774 in 1947 and 1948 to the Guided Missiles Committee of the Research and Development Board and to the Upper Atmosphere Rocket Research Panel, which coordinated scientific research in the new area of space science. The field for rockets available for upper atmosphere research was already crowded, including the army's WAC Corporal and Bumper rockets, and the navy's Viking and Aerobee sounding rockets.[24] When the Air Materiel Command made a formal proposal to the Guided Missiles Committee of the Research and Development Board on February 11, 1949, to use the MX-774 for upper atmosphere research in place of the navy's Viking rocket, the committee decided in favor of Viking.[25]

A last-ditch effort to save the MX-774 in April 1949 pitted the MX-774 against the Navaho. Under the technical leadership of William Bollay, North American Aviation had begun developing a new rocket engine for Navaho, which led to the engines that eventually were used for America's first ICBMs and space launch vehicles, including Atlas, Thor, Jupiter, and Redstone. In 1948, the USAF had ordered North American to double the range of the Navaho to 1,000 miles. Because the existing design did not lend itself to doubling the range, air force research officers at Wright Field worked with the contractor to turn Navaho into a two-stage vehicle with a rocket-powered booster and a winged second stage with ramjet engines,[26] a design that MX-774 supporters criticized for several deficiencies, including problems with its ramjet engine, reentry heating

problems, and guidance system. The MX-774 program ended when Arthur Barrows, the assistant secretary of the air force, declined the request to save the MX-774 program at the expense of the Navaho missile.[27]

Conclusion

Although the MX-774 program was terminated, Convair and the supporters of long-range ballistic missiles inside the USAF continued to press for a similar program. MX-774 contained many technical innovations, such as its gimbaled engines and ultralight airframe design, and other new ideas. While Bossart's team at Convair sought to improve on the V-2 in their design for the MX-774, it marked the beginning of a departure from the conservative style of the von Braun group that had built the V-2 in Germany and then was launching rockets for Army Ordnance.[28] Convair and the MX-774 were out of the competition in 1949, but the air force and other contractors associated with it were still building missiles. The Soviet Union had also embarked on its own missile program, but it too made slow progress in the first years after World War II. Although both superpowers were clearly interested in the possibilities shown by the V-2 missile in World War II, they understood its limitations. In the United States, one of those most responsible for advancing new weapons technology wasn't afraid to talk about those limitations.

5 Missiles in Question

While the army, navy, and air force all had their own arms development programs, the US government had been working to coordinate research and development of new weapons even before it entered the Second World War. The driving force of this effort before, during, and after the war was a bespectacled Massachusetts engineer, entrepreneur, and inventor named Vannevar Bush. Except for some work he did that foresaw the creation of the Internet, Bush's accomplishments have been largely forgotten today. But his influence on wartime and Cold War engineering and science, including the creation of nuclear weapons, is difficult to exaggerate. Bush also exerted a strong influence on the development of missiles in the late 1940s, but this time as a critic. Bush's attitude toward missiles showed that the need for long-range missiles armed with nuclear weapons was not as obvious to policymakers in the years following World War II as was supposed later on in the 1960s and 1970s.

The military services, especially the air force, were not keen on Bush's efforts to coordinate military research and development. The US Army Air Forces had already begun to strengthen its in-house knowledge of new weapons and technologies by setting up the USAAF Scientific Advisory Group, and it also sought out a source of outside advice that was close to the air force. This led to discussions with an air force contractor that resulted in the creation of a think tank that in its early years performed most of its work for the air force. Although Bush helped facilitate weapons development, his attempts to have civilian scientists exercise control over that work ultimately fell short of his wishes.

Vannevar Bush

Bush was already a leading figure at the Massachusetts Institute of Technology when in 1938 he became president of the Carnegie Institute of Washington, one of the largest private supporters of science in the United States. The next year, he was appointed chair of the National Advisory Committee for Aeronautics (NACA), the predecessor organization of the National Aeronautics and

Space Administration (NASA). His influence over science and engineering grew when President Franklin D. Roosevelt established the Office of Scientific Research and Development (OSRD) in June 1941, six months before the Japanese attack on Pearl Harbor brought the United States into the war, to coordinate US military weapons development work with Bush at its head. The National Defense Research Committee, which the president had established the previous year at Bush's urging to support scientific research that could benefit the military, continued as the research arm of the OSRD.

Bush's influence during the war was enhanced by his effective relationship with President Roosevelt. Bush's biographer called Bush and Roosevelt a "good team" despite philosophical differences—before the war, the conservative Bush had been strongly critical of Roosevelt's New Deal. Bush and the OSRD funded the creation of many weapons, devices, and even medical advances related to fighting the war. Bush's work was capped off with his role shepherding the Manhattan Project, which developed the first atomic bombs. Through the National Defense Research Committee (NDRC), OSRD-sponsored research on solid-fuel rockets also led to rockets launched by infantry and from aircraft and ships, most famously the "bazooka" antitank weapon. The US Army Air Forces, however, strongly resisted cooperation with the NDRC because much of the NDRC's missile work duplicated USAAF programs, and the animosity between the NRDC and the USAAF continued beyond the war.[1]

After the OSRD and the NDRC wound down at the end of the war, Bush created new organizations in the restructured US military to coordinate weapons research and development, the Joint Research and Development Board (JRDB) in 1946 and 1947 and its successor, the Research and Development Board (RDB), from 1947 to 1953. As head of the wartime OSRD and then the postwar research boards, Bush wielded great power until his retirement in 1948.

In addition to being the best-known leader of American science and engineering in the 1940s, Bush was the most prominent critic of the idea of long-range strategic missiles, primarily because of the deficiencies of the first missile of that type, the V-2. Despite this criticism, Bush played an important role in developing missiles after the war because of his experience running the JRDB and the RDB. These organizations were just a part of Bush's quest to enlarge the influence of engineers and scientists in setting priorities for military research and development, a quest that was ultimately frustrated by the military.

The postwar research boards and a subsidiary committee on guided missiles worked with limited success to coordinate the missile programs of the three

President Harry S. Truman (*center*) presents James B. Conant (*right*) with the Medal of Merit and Bronze Oak Leaf Cluster as Vannevar Bush stands watching (*left*), May 27, 1948. National Park Service; photo by Abbie Rowe, courtesy of the Harry S. Truman Library

military services. The story of this committee and the research boards illuminates not only the place of missiles in America's arsenal in the early years of the Cold War but also the status of civilian control over the workings of the US military.

The Guided Missiles Committee

During the war, the services all conducted their own research into new weapons, and so the Joint Chiefs of Staff established the Joint Committee on New Weapons and Equipment in 1942 to coordinate research and development among the services and related agencies such as the NDRC. Bush chaired the joint committee, which in its turn established the Temporary Subcommittee on Controlled Missiles, reflecting growing military interest in guided missiles during the war, particularly after the Germans introduced the V-1 and V-2 in

1944. In January 1945, the joint chiefs turned the temporary subcommittee into the Guided Missiles Committee (GMC) to make recommendations about guided missiles for the remainder of the war to the joint committee and the Joint Chiefs of Staff, and to approve plans for future guided missiles. The GMC was made up of officers representing each of the services and civilian experts from OSRD and the National Advisory Committee for Aeronautics, and its work was hampered almost immediately owing to differences between the US Army Air Forces and the rest of the army over who should represent the USAAF on the committee. Bush later recalled that the joint committee could not solve disagreements between the services, and when the disputes were put before the Joint Chiefs of Staff, they would disagree for the same reasons.[2]

Bush had wanted to close down the OSRD immediately after the war ended, and he supported the proposal put forward by a committee made up of military and scientific leaders to replace the OSRD with an institution to be run under the wing of the National Academy of Sciences, the Research Board for National Security. But Presidents Roosevelt and Truman both blocked the idea in their turn, following the advice of the Bureau of the Budget, which believed that no new organization should be set up until the president had a chance to establish a policy covering military weapons research. So the OSRD continued operations into 1946. When Secretary of War Robert Patterson and Secretary of the Navy James Forrestal called for a replacement body that would coordinate scientific research and development for the military, Bush responded in June 1946 by setting up the Joint Research and Development Board, which he chaired. The new body's jurisdiction included research on guided missiles. Bush did not have as close a relationship with Truman as he did with Roosevelt, a change that was symbolized by Truman's resistance to Bush's proposal contained in the 1945 report whose preparation he directed, *Science—The Endless Frontier*, for a national research foundation run by scientists without political or military control. But Bush still enjoyed great prestige with the public and with Congress as a promoter of many technologies.[3]

Bush established himself as a critic of long-range missiles at the end of World War II and in the months that followed. On August 22, 1945, under questioning by military planners who were drawing up postwar plans for the Joint Chiefs of Staff, Bush expressed doubt that a rocket similar to the V-2 could ever be built with a range greater than 1,000 miles, and he stated that it made more sense to concentrate on short-range missiles, because such missiles could become the most effective weapon to defend against attacking aircraft. Bush

stressed the importance of securing overseas military bases for shorter-range offensive missiles.[4] On December 3, 1945, Bush testified to a US Senate committee that other security issues were more pressing than guided missiles. "There has been a great deal said about a 3,000-mile high-angle rocket. In my opinion, such a thing is impossible today and will be impossible for many years," he predicted. Bush told the committee that he disagreed with positive statements about long-range missiles made by USAAF Commanding General "Hap" Arnold.[5]

Although Arnold and Bush had worked together during the war, and Arnold shared Bush's enthusiasm for new and advanced weapons, the two differed on the matter of missiles, and more profoundly over who should control military weapons research and development. Relations between Bush and the USAAF cooled as the air force pressed to assert control over guided missile research. Bush's attempts to strengthen control by civilian scientists over research and development, which included his support for a civilian Atomic Energy Commission, further strained his relationship with the military. Bush took his critical view of long-range missiles to his activities at the Joint New Weapons Committee and the JRDB, including their oversight of guided missiles. When the unification of the armed forces began with James Forrestal's assumption of the job of secretary of defense in September 1947, both Forrestal and President Truman asked Bush to continue his military research coordination work with the new Research and Development Board that replaced the JRDB, which he did for a year before leaving government in 1948.[6]

Bush pursued his case on the missiles' shortcomings as weapons in a book published in 1949, *Modern Arms and Free Men*. "The ton of explosive a V-2 delivered was negligible in comparison with the ten-thousand-ton aircraft raids of the time. Development and production of the V-2 called for the very skills, facilities, and materials that could have been used to much greater advantage in the program of jet pursuit aircraft," Bush wrote in the book.[7] Bush called the V-2 an effective psychological weapon that caused less damage than originally expected. But he admitted that, once launched, the V-2 had been "very difficult" to intercept, which was why there was such great interest in long-range missiles of that kind. Reiterating his opinions expressed in 1945, Bush reckoned the V-2's 200-mile range and payload of a ton of explosives "was nearly at the limit of effective range for a chemically-propelled single-stage rocket." The range of such rockets could only be increased at great cost by reducing the payload, increasing the size of the rocket, or using multistage rockets, but he

neglected to mention the possibilities that different fuels offered in terms of greater range and speed. Bush also questioned the ability of such missiles to strike close to distant targets. He called the cost of these missiles "astronomical" and something that would "never stand the test of cost analysis." Long-range missiles might carry atomic bombs eventually, he wrote. "But as long as atomic bombs are scarce, and highly expensive in terms of destruction accomplished per dollar disbursed, one does not trust them to a highly complex and possibly erratic carrier of inherently low precision."[8]

He was also critical of the V-1. Before World War II, all the elements were ready for a guided missile in the form of an aircraft set to fly automatically to a target carrying explosives, but "practically nothing" happened in this field, except for the V-1 jet-powered winged missile, which served the Germans because they had a large and important target, London, within range of the occupied French coast. The USAAF had a blind spot to the limitations of the V-1, notably the many defenses that successfully stopped it. Bush noted that the USAAF never used the JB-2 missile, and he also questioned the cost of missiles like the V-1 versus their benefit, because crewed bombers had far greater success overcoming enemy defenses.[9]

Bush's book also included his opinions on new jet engines for aircraft, including the ramjet, which he explained would be more useful in short-range high-speed missiles because they would not have to carry a load of oxidizer to react with fuel as in rockets. Bush's opinions reflected the strong interest in ramjets in military circles at war's end. But even as his book was coming out, military interest in the ramjet was fading.[10]

Bush had left government before his book came out in 1949, but his influence on military and government attitudes toward long-range guided missiles up to that time cannot be discounted. Bush's biographer G. Pascal Zachary explained that Bush's opposition to long-range missiles was grounded in his concern that Americans saw "push-button war" as an easy way out of the difficulty and expense of war. In 1946, when both the navy and the air force considered building satellites and launching rockets, Bush discouraged the idea. And while he headed the RDB in 1948, Bush advised Secretary of Defense Forrestal that long-range strategic missiles would be a waste of resources.[11] Given the fact that missile research was still in its early stages and was hamstrung by spending restraint while he was in government, Bush likely did not have to do much else to discourage development of long-range missiles than state these criticisms. During the late 1940s, Bush's opposition to the idea of long-

range strategic missiles stood out because public figures so rarely voiced a similar opinion. Behind closed doors, however, classified reports such as the air force Scientific Advisory Group's *Toward New Horizons* flagged the technical obstacles to long-range missiles, such as the need for better guidance systems along with possibilities these weapons offered.

Not all engineers and scientists shared Bush's opinions about missiles. Nobel laureate in chemistry Harold Urey and Manhattan Project physicists Philip Morrison and Leo Szilard spoke favorably of missiles with atomic warheads at the same 1945 Senate hearings where Bush criticized them. Lawrence R. Hafstad, the director of research at the Johns Hopkins University Applied Research Laboratory and one of the top experts of the time on guided missiles, took the middle ground when he warned in 1946 that the creation of guided missiles would not be a short process because of the many technological advances that would be required.[12] Lt. Gen. Ira C. Eaker, the USAAF's deputy commanding general, told the House Subcommittee on Appropriations on March 6, 1947, that a 5,000-mile-range guided missile could be developed in five years with a development effort equal to that for the atomic bomb. While the air force must retain bombers as its primary long-range strategic weapon, he added that the air force "should, as a wise precaution," support funding experimental work for a long-range guided missile that could become "the primary weapon at some future date, but probably not within 15 years."[13]

The Creation of RAND

Another source of outside support for long-range missiles was created by the USAAF, a source that at the time helped frustrate Bush's hopes for coordinated weapons research directed by scientists and engineers rather than the military. USAAF Commanding General Arnold met on October 1, 1945, near Los Angeles with Donald Douglas, president of the Douglas Aircraft Company; Douglas's chief engineer, Arthur Raymond; Raymond's assistant Frank R. Collbohm; and Edward L. Bowles, a Massachusetts Institute of Technology (MIT) professor who served as a special assistant to Arnold, to discuss developing an "intercontinental guided missile." Bowles and Arnold were contemplating new concepts for conducting research and development, and over the weeks that followed the meeting, discussions between Douglas Aircraft and the USAAF moved toward the air force's general research needs and away from developing a missile.[14]

Shortly after Arnold retired in February 1946, the USAAF and Douglas Aircraft signed a contract establishing what became known as Project RAND (for

Research and Development), which would conduct research on many topics for the air force and later others, and in its early years played a major role making ICBMs a reality. RAND was created at a time when competing visions for postwar research and development were being advanced. Vannevar Bush was pressing for scientist-directed agencies serving the entire military, such as the RDB and the unrealized National Research Foundation to place scientists on an equal footing with the military in directing research and development. Arnold, for his part, wanted to provide the air force with a robust infrastructure for research and development that it controlled. The army and navy already had in-house organizations to develop new weapons, but the air force lacked such an organization and thus sought outside help. The air force had long been using private contractors such as Douglas Aircraft to develop its aircraft, missiles, and other weapons, but RAND became a not-for-profit corporation that assisted the air force by producing studies, strategies, and plans rather than aircraft and weapons. Arnold may have been motivated in part to develop research capabilities outside of Bush's control because of their differing views about the potential of long-range missiles. In historian Alex Roland's critical assessment, the creation of RAND and similar military-funded think tanks "undermined civilian authority" by providing the military a means of circumventing civilian institutions.[15] Others have also questioned the role of RAND in American governance.[16] There appears little doubt that Arnold and the air force wanted a source of scientific and technical advice that they could control, not only on missiles but also nuclear bombs and other new weapons. The ultimate effect, whether intentional or not, was to undermine civilian authority. In its early days, RAND played a key role in pointing the air force to ICBMs as a weapons delivery system.

Satellite Programs

RAND's first research project was not about long-range missiles but artificial satellites of the earth—a subject related to ICBMs, as rockets that can put satellites into orbit can also be used to transport warheads anywhere on earth as an ICBM. The air force and RAND's foray into the field of satellites began in October 1945 when a group inside the navy's Bureau of Aeronautics (BuAer) started work on a proposal to launch a satellite, building on wartime research it had supported on rocket engines using liquid hydrogen as the fuel. This rocket research caused the BuAer group to propose launching satellites using a single-stage launch vehicle based on this advanced rocket technology. When it

became clear that the navy would not support a flight test vehicle program because of its great cost, the BuAer group approached the USAAF.[17] On March 7, 1946, five officers from BuAer and the USAAF met to discuss the navy's satellite work and its proposal that future work to develop a satellite and launch vehicle be split between the two services. The USAAF officers promised to meet again to determine the air force's interest in the navy proposal after contacting the office of Maj. Gen. Curtis LeMay, then responsible for the USAAF's research and development.[18]

LeMay reacted to the news of the navy satellite proposal by working to protect air force interests. LeMay summoned one of the navy officers to tell him that the USAAF would not take part in the navy research work, but he also agreed to again meet with the navy on the subject. At the same time, LeMay directed Project RAND to immediately begin studying the technical specifications and potential uses for a satellite. The USAAF put off further meetings with the BuAer group until it could come armed with copies of RAND's first study, *Preliminary Design of an Experimental World-Circling Spaceship*.[19] The report, dated May 2, 1946, but delivered to the air force ten days later, concluded that artificial satellites were already technically feasible. The RAND experts called for a multistage rocket to launch a 500-lb satellite. The study's chapter on the significance of satellites was written by Louis N. Ridenour, a physicist who had worked during the war at the Radiation Laboratory at MIT, where he helped develop radar devices and edited a series of books summing up knowledge of radar. In the RAND report, Ridenour wrote: "There is little difference in design and performance between an intercontinental rocket missile and a satellite. . . . Consequently the development of a satellite will be directly applicable to the development of an intercontinental rocket missile." Ridenour also predicted that missiles passing through space and even satellites would likely be used to deliver warheads in future wars. While he pointed to satellites as promising "observation aircraft" for the military, he only mentioned observations of weather conditions and verifying the impact points of bombs, missing many other intelligence applications that space-based observations of military installations could and would provide.[20]

The RAND study findings were discussed at a USAAF briefing LeMay held on May 21, 1946. Bringing the payload back to earth without burning up was listed as one of the "major problems" with satellites, the briefing was told, and the RAND study proposed that the solution was "to install wings . . . which will cause the missile to descend gradually as it strikes the atmosphere thereby

allowing it to dissipate the heat generated." The estimated cost to build and launch a satellite in five years was $150 million at the time, or roughly $1.42 billion in 2016.[21]

When USAAF and navy officers met again in June, the air force officers presented the RAND report, and then blocked further discussion of a joint program. The navy pressed on with the BuAer satellite studies until 1948, when money ran out. RAND continued its satellite studies for another year, refining the information pulled together in the initial report.[22] In May 1947, LeMay said the USAAF would "pursue practical aspects of the earth satellite vehicle," which he called "essentially a long range air vehicle."[23]

Much like the air force sought control of missile programs, it also moved to control satellites. USAF Gen. Alden Crawford recommended to his Air Staff colleagues on December 8, 1947, that the newly autonomous US Air Force "establish a satellite project" and have RAND prepare a specification for a satellite with the purpose of testing the vehicle and proving the concept of a satellite.[24] USAF Vice Chief of Staff Gen. Hoyt Vandenberg signed a policy statement on January 15, 1948, that read: "The USAF, as the Service dealing primarily with air weapons—especially Strategic—has logical responsibility for the satellite." Inside the Air Staff, there were reservations. While the Air Staff considered a satellite vehicle to be "visionary, somewhat beyond the state of the guided missiles, of questionable utility, and exceedingly costly, the Navy has been fostering its early implementation with great vigor." An Air Staff memo termed a satellite vehicle "technically, although not economically, possible."[25]

From that time until RAND began studying the potential of military reconnaissance satellites in the 1950s, the air force's main priority for satellites continued to be keeping them out of the hands of the other services. Brig. Gen. Donald L. Putt, then the air force's director of research and development, discussed the great monetary cost of a satellite launch vehicle in a speech on January 11, 1949. He estimated the price tag at about $100 million (about $1 billion in 2016), but his arguments also applied to intercontinental missiles. Putt warned that new military hardware cannot be developed "without due consideration to its potential impact on the national economy," including satellites, which appear to be "economically undesirable." He warned that America's adversaries could win simply by provoking the US government to spend more on weapons than the economy could bear.[26] Even though RAND had established a link in 1946 between the satellite launchers and the rockets that would

President Harry S. Truman signing a proclamation making August 1st Army Air Force Day. *Left to right*, Gen. James H. Doolittle, president of the Air Force Association; Lt. Gen. Hoyt S. Vandenberg, deputy commander of the US Army Air Forces; President Truman; Maj. Gen. Lauris Norstad, director of plans and operations, War Department, General Staff; W. Stuart Symington, assistant secretary of War for Air, July 10, 1947. US Air Force; courtesy of the Harry S. Truman Library

become known as ICBMs, their cost and technical problems turned the air force away from satellites for close to a decade.

The Guided Missiles Committee Reconstituted

While the air force fostered the creation of RAND and moved to keep satellites out of the hands of the navy, Vannevar Bush was setting up the weapons research infrastructure that he hoped would coordinate this work between the competing services. This infrastructure, which in part carried on the work of the bodies that Bush headed during World War II, marked an expansion of the American state because it permanently brought academic and corporate experts

into the management of military weapons development in the Cold War, where before World War II this work had been managed directly by military officers. The Joint Research and Development Board that Bush set up in 1946 did not have statutory authority and thus simply operated under the personal authority of Bush and the secretaries of war and the navy as a stopgap between the wartime OSRD and the Research and Development Board, which was established in law as part of the National Security Act of 1947. The RDB inherited the organizational structure of the JRDB. Under the wing of the RDB, a welter of committees supported by a staff of 250 civilians and about 1,500 expert consultants from academia and industry worked to provide policy and technical advice to the military services, and to implement decisions made by the RDB. In his assessment of the RDB, Defense Department historian Steven Rearden argued that while Bush and his successors provided effective leadership for the RDB, a consensus grew in the government that the committee system was flawed owing to excessive autonomy given to each committee. The RDB lacked the authority and organizational structure to coordinate decision-making because it was generally at the mercy of the services.[27]

Bush described his time leading the RDB as "mostly shadow boxing" because of the RDB's shortcomings, including the welter of overlapping committees. The committees were not effective in limiting duplication because they were "not quite courageous enough" to say no. Bush worsened the situation by insisting on having uniformed officers represent the services on the RDB—the higher the rank, the better—rather than civilian consultants who were then taking a larger role in running military technology programs. As well, Bush and the RDB lacked authority to overrule the joint chiefs or individual services, dashing Bush's hopes to run a more unified research and development program with civilian scientists having a strong controlling role. The joint chiefs frustrated Bush's efforts to set up a group of civilian scientists to provide independent strategic and tactical advice on new weapons by allowing the formation of what became known as the Weapons Systems Evaluation Group, but under the control of the joint chiefs instead of the civilian scientists at the RDB, as Bush had wanted. Contrary to Bush's hopes, these committees helped enhance the influence of the military over civilians in universities and private industry. The interservice feuding that marked the time exacerbated the weaknesses of the RDB and its committees. "We really had no authority whatever over anything," Bush complained after leaving the RDB in frustration after only a year heading it.[28] The December 1948 report of the Task Force on National

Security Organization called for closer coordination between the joint chiefs and the RDB to ensure better use of advances in weapons technology. The RDB chair was given more powers when the National Security Act was amended a few months later and the RDB's staff was reorganized, but the changes did not enhance the RDB's effectiveness.[29]

In August 1946, the Guided Missiles Committee had moved from the jurisdiction of the Joint New Weapons Committee of the joint chiefs to the JRDB, where it was charged with the "continuing study, evaluation, improvement, and allocation of research and development programs on guided missiles" and "the formulation of an integrated program" for missiles as part of an integrated national defense program. Its membership included its chair, physicist and MIT president Karl T. Compton, who agreed to chair the GMC for a short time as a favor to Bush, and board members Edwin R. Gilliland from MIT and Hugh Dryden of the NACA, along with representatives of the army, navy, and air force.[30] In January 1948, the GMC was reconstituted again after the RDB formally replaced the JRDB as the body coordinating military research in the fall of 1947. This latest GMC, with roughly the same lineup as before, of three civilian members and two representatives each from the army, navy, and air force, had the objective of implementing the mandate of the RDB in the field of guided missiles.[31] When Compton replaced Bush as RDB chairman in October 1948, he was succeeded as GMC chairman for a short period by Purdue University president Frederick L. Hovde, a chemical engineer who had been close to Bush. In 1949, Clark B. Millikan, a Caltech aeronautical engineer and expert on rocketry, took the chair of the GMC, marking the first time that the committee was clearly led by a figure with experience in the field of guided missiles.[32]

Like the RDB, the GMC proved to be ineffective. Late in 1948, the GMC's own secretariat admitted that there was no national guided missile program but three programs, one for each service. Brig. Gen. James F. Phillips, the air force's member of the RDB secretariat, pointed to civilian members on the GMC and other RDB committees as the source of this problem, given the fact that committee service members were required to uphold the desires of their services: "It is no secret that 'when the chips are down' on a controversial problem, the civilian committee chairman and other civilians rarely vote."[33]

The US government set up the RDB and the GMC in an attempt as a technological system builder to impose unity from diversity. This attempt to create unity met strong resistance from all three branches of the US military, which

sought to preserve control over their own weapons programs. Like the hopes of the architects of military unification, the desire to create a coherent national missile program through the agencies of the RDB and the GMC failed to materialize. Bush had hoped to give civilian scientists and engineers more control over military weapons programs. Instead, military influence over industry and academia began to grow during that time.[34]

The Guided Missiles Committee Looks at Long-Range Missiles

In the summer of 1948, the GMC took its first serious look at long-range rocket missiles when it formed an ad hoc subcommittee on long-range rockets to study "the problem of proper balance of emphasis in the long range missile program" and recommend action for the committee. The subcommittee was also charged with examining the possible effect on the national guided missiles program "of the absence of any specific project" for the development of long-range rockets, earth satellite vehicles, long-range ramjets, or associated equipment development programs. The subcommittee was chaired by Dr. Edwin R. Gilliland of MIT and included one member from each of the services, including Col. Holger N. Toftoy, the ordnance officer who supervised the army's missile program.[35]

In its report, drawn up after a single meeting on July 20, 1948, the subcommittee recommended "no specific project" for a rocket missile with a range greater than 500 miles be started "because of the present state of the art and the cost involved." Instead, it suggested that RAND expand its study of earth satellite vehicles to encompass long-range rockets in general, and that the study operate on a continuing basis to keep "the optimum design abreast of the art" and to determine the military worth of the vehicle. RAND should be able "to recommend initiation of the development phase of the project at the proper time." Finally, the subcommittee recommended that General Electric Company (GE), which was Army Ordnance's contractor on the Hermes Project, be given the task of developing a 500-mile rocket missile "as a logical step beyond their present 150 mile missile," then known as Hermes C1.[36]

After the full GMC approved the subcommittee's report on September 15, Toftoy ordered GE to begin work on a 500-mile rocket as part of Hermes and to use the group of German engineers in the army's employ headed by Wernher von Braun. Toftoy also decided that because the budgets for fiscal years 1949 and 1950 had already been established, the project would have to get by with-

out extra funds for nearly two years until July 1950, when the 1951 fiscal year would begin. With this financial constraint, Army Ordnance duly waited until July 1950 to begin a formal study of a 500-mile range tactical missile that eventually became known as Redstone.[37]

Experts outside the air force did not see an immediate need for long-range missiles. The air force, through its representatives on the GMC and the subcommittee, agreed to let the army begin building a long-range missile, although no reason has been found for the air force's action. Possibly, the air force believed that the 500-mile range was too short to threaten air force prerogatives, or that the budget problems affecting all missile research meant that the army would not be able to make much progress with the Redstone missile. Army Ordnance, which at the time was seeking control of many types of missiles at the expense of the air force, declined to run with the opportunity to take a lead in the field of long-range guided missiles because of tight budgets. The GMC did not consider long-range rocket missiles again until 1951.

The US Air Force had set a low priority for long-range offensive missiles, and this priority was matched by a report of a technical evaluation group set up by the Guided Missiles Committee.[38] Using that report, the Joint Chiefs of Staff produced two priority lists for guided missiles. The first list, broken down by primary category, put surface-to-surface missiles fourth and last. A second list broken down by subcategory put surface-to-surface long-range missiles with atomic warheads in eighth place and long-range missiles "with high explosive and incendiary warheads" eleventh out of thirteen subcategories. Top priority went to air defense missiles.[39] The air force found the low priority for long-range surface-to-surface missiles troublesome because its two existing programs in this category, Navaho and Snark, were consuming a larger portion of air force missile funds than their priority merited. As far as the air force was concerned, this priority problem complicated its efforts to defend its missile programs during the months of deepened austerity in 1949 and early 1950.[40]

Conclusion

The most prominent American figure in science in the 1940s, Vannevar Bush, was also a critic of long-range missiles, pointing out the deficiencies of the German V-2 ballistic missile as a weapon, including its great cost and poor accuracy. Bush directed bodies coordinating military research during World War II and after the war up to his retirement in 1948, and although there is no direct evidence that he directed them to avoid supporting such missiles, the

matter came before them only once, and they supported the sole idea of building a missile with the modest range of 500 miles, a plan that languished in the army for more than two years. The work of Bush and the Guided Missiles Committee showed that military interest in long-range rocket missiles was not yet strong in the late 1940s, in part because of the great limitations of the V-2. Although the air force and Bush differed on the need for coordination of military research, and the air force acted to bolster its own research program by helping found the RAND Corporation, their attitudes in the late 1940s toward long-range missiles were similar. RAND would eventually come to play a crucial role in shaping air force attitudes to missiles.[41] But in 1948, the GMC inside the Pentagon, where all the US military forces were represented, decided that long-range ballistic missiles that worked effectively as weapons delivery vehicles seemed to be too far off and too expensive to merit a high priority for scarce funds for military research and development. Missiles designed to defend against incoming aircraft had a much higher priority.

6 Truman Moves on Missiles

In January 1949, Harry S. Truman was sworn in for a second term as president, this time in his own right after his surprising victory in the 1948 election over Republican Thomas E. Dewey. Truman's first term had been difficult one, as America and the world at large adjusted to the end of World War II and the transition to the Cold War between the United States and the Soviet Union. With the support of Congress, Truman had imposed tight budgets on the military and passed legislation reorganizing the military that fell short of the hopes of those who envisioned a more centralized structure for the US armed forces. Although the Republican majorities in the outgoing congress were overturned with a Democratic Congress in the 1948 election, many Democrats were conservative Southerners who, like the Republicans, wanted to keep a lid on spending.

Truman's second term proved to be more challenging than the first. Many of these challenges involved the military, including one of the most important decisions of his presidency, when news of a Soviet nuclear explosion signaled the end of America's nuclear monopoly. In an episode that was little noted, the president also got involved in military missile programs. Although Truman's intervention in missile programs did little to affect the development of intercontinental ballistic missiles, it showed that during his time in office, he and most American policymakers saw missiles as a way to defend against Soviet bomber aircraft rather than as a means of delivering nuclear weapons.

A New Broom in the Pentagon

In 1949, Truman continued his military economy drive with a proposed $14.4 billion defense budget for fiscal year (FY) 1950, rejecting the call of the Joint Chiefs of Staff for a much higher $23.6 billion budget for FY 1950. And his administration planned an even smaller budget for FY 1951 of $13.5 billion.[1] The policy of military budget restraint was enthusiastically supported by Truman's new secretary of defense, Louis A. Johnson, who entered that office on March 28,

1949, upon the resignation of James V. Forrestal.[2] A West Virginia lawyer who had served as assistant secretary of war from 1937 to 1940, Johnson gained notoriety both for his own presidential ambition and his dedication to Truman's goal of reining in military spending. Johnson had served in the army in World War I and had later headed the American Legion, but more importantly, he had stepped forward to become Truman's chief fundraiser in the 1948 election. He began his term of office with sweeping changes to the Pentagon, including reassigning 25,000 employees and eliminating several service boards.[3]

The ill will between the services outlasted Forrestal's term as secretary of defense, and probably contributed to his leaving the post and his suicide shortly afterward. Johnson was also considered to be friendlier to the air force than Forrestal, who had been secretary of the navy before his promotion to secretary of defense.[4] The new defense secretary wanted to save money by making armed forces unification a fact, and Congress assisted him with the passage that August of amendments to the National Security Act that established the Department of Defense in place of the ineffective National Military Establishment, and gave the secretary of defense more control over all three services by making him the sole voice for the military at the cabinet table. But the disagreements between the services continued until they were temporarily subsumed in 1950 by the more immediate problems of the Korean War.[5]

Johnson's first months in office took place against the background of events such as the first Soviet atomic bomb test, the latter stages of the Berlin airlift, and the communist takeover of China. Throughout this time, Johnson maintained that the biggest threat to the national security of the United States was bankruptcy resulting from unrestrained spending rather than war with Russia. Johnson and Truman had support in urging spending restraint from large segments of Congress and the public. Before he left his government post, Vannevar Bush had pushed to hold down annual defense spending for research and development for FY 1949 and beyond at $500 million. Bush was concerned that greater spending would lead to waste from mediocre engineers and scientists because the supply of quality people was limited.[6]

On April 23, 1949, during his first month in office, Johnson abruptly canceled the navy's long-awaited new supercarrier *United States*, which the navy saw as a key part of its own nuclear strategy. Secretary of the Navy John Sullivan resigned three days later, and the anger in the navy created by the cancellation led to an episode known as the revolt of the admirals. Naval officers and navy supporters began publicly attacking the US Air Force's procurement of B-36

President Harry S. Truman (*right*) with Louis Johnson (*left*) and Gen. Harry Vaughan (*center*) viewing the Army Day parade in Washington, DC, on April 6, 1949. National Park Service; photo by Abbie Rowe, courtesy of the Harry S. Truman Library

bombers and air force doctrine on the use of nuclear weapons. Angry naval officers charged that the B-36 bomber was a poor aircraft built by a well-connected contractor. As a result of the controversy, in August 1949, the House Armed Services Committee held hearings into the B-36 that addressed the services' missions and roles, the USAF's continued monopoly of atomic bomb delivery capabilities, and the services' shares of defense budgets. When Chief of Naval Operations Adm. Louis E. Denfeld criticized how the Joint Chiefs of Staff and Johnson treated the navy during his public testimony to the committee in October, President Truman fired him. Denfeld's removal marked the end of the revolt, and even though the hearings upheld the air force's confidence

in the B-36 bomber, Denfeld's testimony was seen in the navy as a crucial defense of naval aviation against those who wanted to eliminate it.[7] The creation of the Department of Defense and the quelling of the admirals' revolt in 1949 marked the completion of the Truman administration's reorganization of the US military. Although each new administration made structural changes over the years that had the effect of increasing the power of the secretary of defense, this organizational scheme remained in place for the rest of the Cold War and until the reforms that followed the terrorist attack on the United States on September 11, 2001.

Missile Dispute Reemerges

The turbulence roiling the military when Johnson took over also affected missile programs. The army and the air force had apparently settled their previous differences over control of missile programs in 1947 at the time of the creation of the US Air Force. But shortly after Johnson became defense secretary, the US Army renewed its effort inside the Guided Missiles Committee (GMC) and the Joint Chiefs of Staff to enlarge its role in the missile field. Acting Secretary of the Army Gordon Gray wrote to Johnson on May 16, 1949, pressing the army's case to take over operational control of surface-to-surface and surface-to-air missiles because these types of missiles were considered "an extension of present conventional type artillery" and "inherent in land combat." Gray also proposed that the army take over research and development for these missiles. The USAF strongly opposed Gray's proposal, calling it a violation of the 1947 agreements between the army and the air force, but the navy supported the army as the army and navy worked together to establish roles giving them access to nuclear weapons.[8]

The dispute also drew in the GMC and Secretary Johnson, whose hands-on style saw him become far more involved in missile programs than his predecessor. In response to Gray's memorandum, Johnson asked the Joint Chiefs of Staff on May 25 "whether, and if so, to what extent, how and when, operational responsibility for various types of guided missiles should be assigned to the several services." The request was passed to the GMC, which turned down the army's proposal because it and the Research and Development Board had recently approved a policy rejecting the allocation of broad categories of missiles to a single service.[9] The RDB also wished to defer making recommendations on assigning missile research and development responsibilities until the joint

chiefs had made operational assignments.[10] Similarly, the joint chiefs declined to decide on the army's request for assignment of operational responsibilities for long-range surface-to-surface missiles until more was known about their operational capabilities.[11]

Soon a compromise for the missile dispute was in the works as staff officers attached to the joint chiefs drew up a document to satisfy the various services. A draft policy that contained proposals approved by Gen. Lawton Collins, the army chief of staff, formed the basis of a proposal Gen. Omar Bradley, chairman of the Joint Chiefs of Staff (JCS), sent to Secretary Johnson on November 17, 1949. Although Bradley suggested assigning operational, and by implication research and development, responsibility for some antiaircraft, air-launched, and short-range guided missiles, his proposal was silent on the matter of long-range guided missiles. Bradley wrote that new weapons such as long-range missiles would be available to any service that decided it needed them to carry out its required functions, as approved by the JCS and the RDB.[12]

When the army launched its bid to win control of all surface-to-surface missiles in May 1949, it also asked the joint chiefs to approve its bid for a tactical missile armed with a nuclear warhead, which it contemplated deploying in Europe under the umbrella of the North Atlantic Treaty Organization. The navy, which also wanted to deploy nuclear-armed missiles, supported the army's proposal. At Johnson's behest, the joint chiefs placed the question before a three-member committee made up of the chair, Army Lt. Gen. John E. Hull, and two prominent scientists, Frederick Hovde, president of Purdue University and a former chair of the GMC, and physicist Norris E. Bradbury, the director of the Los Alamos National Laboratory. The committee's report in September 1949 suggested that by 1954, sufficient fissionable materials would be available to allow nuclear warheads to be used on four types of missiles, including two air force missiles, the Snark and the air-to-surface Rascal missile, and one missile each from the army and navy. By early 1950, the committee's report had won the approval of the joint chiefs and Secretary Johnson. While the air force did not stand in the way of the other two services during this discussion, it urged caution to ensure that sufficient nuclear weapons remained available for the air force. The discussions showed that the services were capable of some cooperation in the area of missiles. More importantly, the Hull committee began the process of setting technical requirements for nuclear warheads on guided missiles, a process the air force had tried and failed to begin three years earlier with its Mastiff program.[13]

Economy Drives

While Johnson, the services, and the RDB grappled with the issue of who had control of missile programs, the secretary of defense continued to apply pressure on missile programs to save money as part of a promise he had made to cut $2 billion out of the $14.5 billion in annual military spending for FY 1950. Johnson wrote Research and Development Board Chairman Karl T. Compton on July 15, 1949, calling for major cutbacks in spending on guided missiles as part of a $50 million reduction he had ordered out of the Defense Department's $500 million research and development budget.[14]

Over the next few months, the GMC resisted Johnson's cutbacks. GMC Chairman Clark Millikan urged the RDB in August 1949 to make an "aggressive presentation" on the missile program to both Johnson and President Truman to deal with what he called the insufficient information that the committee believed Johnson had. Millikan defended the cost of missile programs, explaining that the development and testing of missiles was more expensive than crewed aircraft because few, if any, missiles could be used more than once, while a single piloted aircraft could be flown over and over in flight testing. Missile budgets were being cut just as missiles were moving into production and testing, when costs could be expected to increase.[15] When GMC officials complained about cuts made by RDB staff to missile programs, RDB executive secretary Robert F. Rinehart responded that the RDB was left with no choice but to decide the cuts itself or risk having decisions made by less well-informed people outside the RDB. Although the RDB suggested $15 million worth of cutbacks, Rinehart said Secretary Johnson's management committee believed that the RDB "had not been particularly responsive."[16]

The Stuart Board

As 1949 drew to a close, the fate of missile programs was moved to a higher forum that would also consider which services should control missile research and development and which would have operational control over the new weapons. Johnson was dissatisfied with the responses from the joint chiefs, the RDB, and the GMC to his requests for cutbacks in the military missile program, and on December 13, 1949, he brought his concerns to a meeting of the Armed Forces Policy Council, an advisory group made up of the service secretaries and the Joint Chiefs of Staff. The meeting convened with an agreement to have Air

Force Secretary Stuart Symington report on the missile program, with a view to encouraging maximum coordination of effort and effective control of the missile programs.[17] Symington's suggestion a week later—that the services form the Interdepartmental Guided Missiles Board to draw up reductions to the services' missile programs—was accepted, and the new board became known as the Stuart board after its chairman, Air Force Assistant Secretary Harold C. Stuart. When the Stuart board reported to the service secretaries on February 3, 1950, it could agree unanimously to continue only fourteen missile programs, including the air force's major long-range missile project of the time, the Navaho winged missile. The board was deadlocked on recommendations for the cancellation of ten other missile projects.[18]

The Stuart board had failed to make the cuts Johnson wanted, and on February 15, the secretary of defense expressed his continued dissatisfaction with the guided missile program, and "stated his belief that an outside agency or individual should be brought in to straighten it out."[19] The matter was referred to the joint chiefs, who a month later recommended to Johnson that three missile programs be discontinued and others downgraded to technology development programs that would not necessarily lead to missiles, including the USAF's long-range Snark. Navaho was continued. The joint chiefs approved a Stuart board recommendation to set up an Interdepartmental Operational Requirements Group to advise both the Joint Chiefs of Staff and the three services about the coordination of the three services' guided missiles programs. The group would be called upon to draw up programs for guided missiles research and development, and for production of operational guided missiles. The JCS also proposed to review missile programs on an annual basis. Johnson, for his part, was dissatisfied with the JCS proposals because in his view the cutbacks did not go far enough, but after meeting with the joint chiefs and RDB officials on March 20, he finally agreed to the proposals on the condition that the Interdepartmental Operational Requirements Group report to him every ninety days.[20]

The joint chiefs also suggested changes in assignments of responsibility for missiles: "Surface-launched guided missiles which supplement, extend the capabilities of, or replace Air Force aircraft (other than support aircraft) will be a responsibility of the U.S. Air Force as required by its functions."[21] Symington's special consultant Thomas G. Lamphier summed up the results of the Stuart board process this way: "The Air Force now has formal and exclusive responsibility

for strategic guided missiles." The creation of the interdepartmental group "is, in effect, a dictate from the JCS to itself to arrive at a realistic priority listing for the research and development of guided missiles, and to do so soon." But Lamphier warned that the navy Triton missile and the army Hermes B-1 and II ramjet test missiles, which were in the design and study phase, could still compete with the air force Navaho missile in the strategic field.[22] This decision, at least in the view of the air force, effectively assigned long-range surface-to-surface strategic missiles to the air force. As well, it marked the effective removal of decision-making on military missiles from the Guided Missiles Committee and the Research and Development Board to the Joint Chiefs of Staff and the Secretary of Defense. The already weak civilian influence over US guided missile research and development was further diminished.

The End of the Nuclear Monopoly

While Johnson and the Joint Chiefs of Staff were grappling with the issue of missile programs in 1949, news arrived that the Soviet Union had succeeded in ending the American monopoly on nuclear weapons. Soon the Truman administration and the president himself were engaged in making the most important decision involving US nuclear weapons since the end of World War II. This was a decision that would eventually have a decisive impact on the development of long-range missiles.

The Soviet Union had begun work on its own atomic bomb and long-range bomber aircraft before World War II ended. Assisted by spies in the United States, Canada, the United Kingdom, and elsewhere, the Soviets were able to keep track of developments inside the top secret Manhattan Project, which produced the first atomic bombs for the United States. Truman's disclosure to Soviet dictator Josef Stalin at Potsdam in July 1945 of American possession of the atomic bomb, and the subsequent bombing of Hiroshima and Nagasaki, drove home to Stalin the power and importance of this new weapon, and it was only then that Stalin ordered his team of nuclear physicists headed by Igor V. Kurchatov to accelerate their work on developing nuclear weapons.[23]

The Soviet nuclear program operated in secrecy while American experts tried to guess what the Soviet government was doing to create a nuclear bomb of its own. In the years following the end of World War II, American estimates of when the Soviets would have a nuclear weapon had varied widely. But even as the first American nuclear weapons were dropped, some knowledgeable Ameri-

cans realized that the Soviet bomb would not be far off, and this concern deepened particularly after the 1946 revelations of Soviet espionage. Early in 1949, the military began a program aimed at detecting any nuclear tests taking place inside the Soviet Union. On the night of September 3, 1949, a USAF B-29 weather plane flying between Japan and Alaska detected radioactive particles in the air along its route. The particles were picked up in filter papers exposed to the atmosphere outside the aircraft. In the days that followed, the initial positive result was verified by other aircraft carrying filters and from rainfall captured outside Soviet territory that contained radioactive fallout. The Soviet Union had exploded a nuclear bomb in the last few days of August. After experts further verified the findings, the results were taken to David Lilienthal, the chairman of the Atomic Energy Commission, who on September 20 brought the news to President Truman that America had lost its nuclear monopoly. Three days after being told about the Soviet nuclear explosion, and after a debate about whether the news of the test should be made public, Truman had his press secretary release the unsettling news to the White House press corps.[24]

The revelation of the Soviet nuclear test prompted the American military to review its preparations for confrontation and war with a Soviet Union that possessed its own nuclear weapons. By that time, nuclear physicists had already hypothesized a weapon a thousand times more powerful than the two bombs used in Japan. Development of this weapon soon came to the fore as a possible response to the news of the Soviet nuclear advance. The development of this bomb would divide American nuclear physicists and would also open the way to a new weapon: the intercontinental ballistic missile.

Thermonuclear Debates

The news of the Soviet bomb launched a debate behind closed doors at the Atomic Energy Commission about whether the United States should develop a new and much more powerful type of nuclear bomb, known variously as the thermonuclear bomb, the hydrogen bomb, or the fusion bomb. Existing atomic or fission bombs rely on the energy released when a large atomic nucleus, such as that of uranium or plutonium, is split. The thermonuclear bomb releases a much larger amount of energy and radiation when an explosive nuclear chain reaction, where atoms divide as in the fission bomb, compresses atoms of the lightest element, hydrogen, which fuses to form a heavier element, helium. In

1949, the idea of the thermonuclear bomb was not a new one—it first arose in 1941 in a conversation between Enrico Fermi, the Italian refugee physicist who was then about to create the first nuclear reactor, and Edward Teller, a Hungarian physicist who had immigrated to the United States in the 1930s. Both soon went to work in Los Alamos, where Teller began to analyze theoretical problems related to this proposed new weapon. While wartime work at Los Alamos revolved around creating the fission bombs first exploded in 1945, some resources were spent on learning the basics of thermonuclear reactions, but many problems were identified that would slow development of such a weapon. A concept for a thermonuclear bomb under consideration for development during the war was put aside because of several important technical problems.[25]

When the war ended, most of the physicists at Los Alamos returned to their universities, including Teller to the University of Chicago. But he and other scientists continued their theoretical work on the bomb, which was often known as the Super, assisted by computations performed on early computers. While physicists agreed that the explosion of a fission bomb would be necessary to create the temperatures of millions of degrees needed to set off the thermonuclear reaction, the means of transferring this energy in an effective fashion remained elusive. A German scientist who had become a British citizen and was employed by the British government, Klaus Fuchs, took part in some of the early work on the thermonuclear bomb and passed information about it to the Soviet Union, a fact that became known to authorities before his arrest in 1950. While theoretical work and experimentation with fission weapons and hydrogen isotopes continued during the late 1940s, by the time the Soviets had exploded their first fission bomb in 1949, the thermonuclear bomb remained far from becoming a reality.[26]

Many of the scientists who helped create the first fission bombs at Los Alamos had serious misgivings about the destructive power of their creation, and these feelings intensified as reports came in of the destruction of Hiroshima and Nagasaki. The scientists' concerns over nuclear weapons and the growing security demands of the Cold War were symbolized in the creation of the *Bulletin of the Atomic Scientists*, whose many prominent contributors included Teller and J. Robert Oppenheimer, the scientific director of Los Alamos. But as the Cold War deepened, many Americans grew more concerned about the dangers posed by the Soviet Union, particularly in the fall of 1949, with the news of the Soviet nuclear bomb and the communist takeover of China. As the discussions over the future of the thermonuclear bomb continued that fall, politics

played an increasingly important role, along with the technical and personal issues between scientists and decision makers.[27]

That October, the General Advisory Committee of the Atomic Energy Commission met to consider the future of the thermonuclear bomb program. The committee was chaired by Oppenheimer and was made up of scientists including Fermi but not Teller. At a meeting in Washington on October 29 and 30, the advisory committee voted unanimously not to proceed with the thermonuclear program, citing both moral and technical reasons, including the potentially unlimited power of this type of bomb. The majority report signed by six of the eight scientists warned that such a bomb "might become a weapon of genocide," and a minority report supported by two others contained even stronger warnings. On November 2, three of five members of the Atomic Energy Commission also voted against proceeding with thermonuclear development. But the commission vote came a day after a senator inadvertently revealed the possibility of thermonuclear bombs in a broadcast interview, and as the month went on, the media gave more coverage to the previously secret concept.[28]

When Truman received the report of the AEC's deliberations, he charged a special committee of the National Security Council to examine thermonuclear weapons. The committee was made up of AEC Chairman Lilienthal, who had cast the deciding vote in the commission against the thermonuclear bomb; Secretary of Defense Johnson, already known as strongly supporting the weapon; and Secretary of State Dean Acheson. Proponents of thermonuclear bombs—including Teller and other scientists, the Joint Chiefs of Staff, and members of Congress—lobbied the committee, as did the opponents of the weapon. In the end, the decision came down to Acheson, who despite strong opposition from within his department concluded that in the wake of the news about the Soviet fission bomb, he could not see "how any President could politically survive a policy of not making the H-bomb."[29]

On January 31, 1950, the special committee met, and with Johnson and Acheson in favor, it voted to recommend that the president proceed with a program to develop thermonuclear weapons. Their seven-minute meeting with Truman later that day showed that the president had already decided to go ahead with the new weapon. When Truman asked if the Soviets could build such a bomb, all three committee members nodded in agreement, and when Lilienthal made a last attempt to change the president's mind, Truman said, "What the hell are we waiting for? Let's get on with it." The decision, which was made public that day, kicked off a major scientific and engineering program that would

require nearly three years to bear fruit. Only then would its effects be felt on military programs such as missiles.[30]

Calls for Change on Missiles

As Truman decided on thermonuclear weapons in January 1950, the leadership of the US military, including Secretary of Defense Johnson, was becoming more disenchanted with its guided missile programs. The Joint Chiefs of Staff and the service secretaries failed to rationalize missile programs with the Stuart board in February 1950, and then the joint chiefs organized the Interdepartmental Operational Requirements Group to expedite missile programs within the budgets of the time. But in the eyes of many leaders, bigger changes were needed. Lyndon B. Johnson, an ambitious US senator from Texas, called on February 13 for a review of missile programs, saying that the United States was falling behind other countries in this field and had no missile that could defend the country. Hubert E. Howard, chairman of the Munitions Board, which supervised production of weapons for the military, expressed strong dissatisfaction with military missile programs to Defense Secretary Johnson on February 14. Howard recommended that Johnson "assign to a single individual the sole responsibility for the definition and allocation of proper fields of research and development in guided missiles and for coordinating the Services' activities in this area." This individual should be able to turn his responsibilities back to the Research and Development Board after six months on the job. Howard also urged that the individual selected be a civilian to avoid a conflict of interest, although a military officer "may have to be accepted as a last resort." He suggested one civilian, Edward Falck, who had worked at the War Production Board, and two military officers.[31]

The next day, Secretary Johnson told the joint chiefs and the service secretaries that he planned "to establish a czar in the field of guided missiles for approximately three months." Johnson suggested that the job be given to either Falck or John McCone, a business executive who had served on the Finletter Commission on Air Power. The Joint Chiefs of Staff persuaded Johnson to "suspend action" until the chiefs could make a recommendation on the Stuart board report.[32] The fact that both Johnson and Howard had a common name for the missile czar suggests that the two men and probably other people had discussed the matter. But a month later, when the joint chiefs agreed to the interdepartmental board as a muddy resolution to the interservice missile disputes, the drive to appoint a missile czar stalled out for a few months.

Political Tensions

The debates over missiles in the early weeks of 1950 took place as political tensions were rising in Washington, DC, for reasons that went beyond the Soviet nuclear test and the debate in the media over thermonuclear weapons. That January, Dean Acheson and the State Department were under political attack for having "lost" China to the communists. These attacks received additional credence that same month, when Acheson defended his friend Alger Hiss, a former State Department official, after Hiss was sentenced to five years in jail for perjury for untrue statements about passing secret documents. Rumors spread of Soviet spies obtaining atomic secrets, and they were confirmed on February 2 when Klaus Fuchs was charged with espionage in the United Kingdom. On February 9, a then-obscure US senator from Wisconsin named Joseph R. McCarthy rose to fame when he delivered a speech charging that the State Department was infested with communists and claiming to have a list of them. America's anticommunist hysteria of the 1950s was under way.[33]

Even as he gave the go-ahead to thermonuclear weapons, President Truman hoped to keep the lid on military spending. But in April, the National Security Council produced a report known as NSC-68 that called for a major increase in defense spending, reflecting a growing consensus inside the State Department and the military that increased spending was necessary. NSC-68 became one of the most famous and controversial documents of the Cold War. In that environment, the Korean War began with the North Korean communist invasion of South Korea on June 25. Truman responded to this act by sending military forces to defend South Korea under the flag of the United Nations (UN). Truman also loosened the restraints on defense spending and made NSC-68 government policy. The start of the Korean War marked the beginning of massive increases in spending on all military programs, including guided missiles.[34]

The spread of communist regimes in eastern Europe and Asia, coupled with the news that the Soviet Union had its own atomic bomb, raised fears in the United States and elsewhere about the possibility of nuclear war. With the Korean War underway and American forces fully committed to the war, these fears were heightened when China sent forces into Korea in October 1950 and people like the UN commander in Korea, Gen. Douglas MacArthur and Truman himself spoke of using nuclear weapons in the conflict. This raised the possibility

that the Soviet Union could send nuclear-armed bombers to the United States, and one means of defending against them would be missiles.[35]

Truman and Missiles

Prior to the summer of 1950, the matter of missiles had not reached the president's desk, except as a part of larger budget decisions. But that was about to change. Despite years of promises, "not one guided missile was operational" in June 1950. Aside from interservice rivalries over guided missiles, they remained one of the military's smaller concerns. Defense Department historian Doris M. Condit explained that the military guided missiles program also "suffered from too many cooks—the Research and Development Board to review and coordinate service programs, the Munitions Board to see that industrial capacity met military requirements, the JCS to adjust service requirements," plus other bodies to regulate atomic warheads. Increasing disquiet over the lack of missiles led the president and the secretary of defense to supersede the complicated and ineffective committees that were supposed to direct missile programs with a "czar" to run the programs before guided missiles could fall so far behind that they would become a major problem.[36] The tight budgets that slowed missile development came to an end with the increased funds that began to flow after the Korean War began, and the administration, with agreement from Congress, implemented the arms buildup called for in NSC-68.

President Truman's main involvement in guided missile programs in the first five years of his administration was indirect. His policy of restraining all military spending from 1945 to 1950 restricted the funds available for missiles. When Truman loosened the military's purse strings with the onset of the Korean War, more money became available for missile development, among many other things. Truman's 1948 decision to release $16.2 million for missile research as part of a number of defense budget actions was a rare instance of direct presidential action on missiles in the late 1940s. The president's decision in January 1950 to proceed with the development of the thermonuclear bomb proved to be crucial to the creation of American ICBMs, but this would not become apparent until after Truman retired in 1953. Truman spoke about missiles only in passing during his time in office, and his memoirs, which were published before Sputnik, made only one reference to missiles, again in passing.[37] Political scientist Richard E. Neustadt wrote that Truman did not look for issues to deal with but was happy to decide on them when they were brought to him. The issue of guided missiles landed on the president's desk for the first

time in the summer of 1950.[38] In July, just days after the Korean War began, the military's problems with missiles became a matter of public record when a *New York Times* article contended that the missile program had "been marked by a great deal of duplication," in part because of the "so far insoluble problem of allocating the various types of guided missile warfare among the respective services."[39]

Soon new calls were made inside the Pentagon for a strong individual to take over the military's missile programs. The air force's new under secretary, John McCone, who months before had been under consideration to be missile czar, wrote US Air Force Secretary Thomas Finletter on August 10 warning that the United States needed to "maintain in being at all times a powerful counter-offensive capacity, first as a deterrent," and that this deterrent rested "in the development, perfection and production of supersonic ground-to-air guided missiles" to defend against Soviet bombers. McCone wrote that poor organization and a lack of funds had held up progress on missiles. He called for the creation of a program with the highest priority to develop the "entire field" of guided missiles "under the most capable man who can be drafted." While the military had spent $94 million on missiles up to August 1950, McCone urged that this spending be increased to $2 or $3 billion. Five days later, McCone wrote Finletter that the ineffective missile programs being run by the three services should be replaced by a single missile program under an individual with a "Pentagon Board of Directors" to link with various branches of government. "It will be more like the Manhattan Project," McCone suggested. He stressed the need for defensive missiles and did not specifically mention long-range guided missiles.[40]

About that time, Finletter asked a former leader of the Manhattan Project, Army Maj. Gen. Kenneth D. Nichols, about setting up a similar project for missiles. "I consider it impossible to set up a Manhattan Project, and in particular, to establish the degree of secrecy that is essential to avoid interference with any such command," Nichols responded. "You can only do it in time of war." Finletter replied: "You think how to do it."[41] The calls for firm direction over missiles were also heard outside the air force. The under secretary of the navy, Dan Kimball, wrote Defense Secretary Johnson on August 21 to call for a director "of national reputation with broad experience and proven competence" to accelerate the guided missiles program by coordinating the work of the various committees involved in directing missile programs.[42] By then, the RDB was developing a set of directives for a "Director of the Guided Missiles Project."[43]

K. T. Keller

Louis Johnson resigned as secretary of defense at Truman's request on September 19, taking with him much of the blame for setbacks in Korea and the effects of the military austerity program Johnson had championed at the president's behest. Gen. George Marshall, the wartime army chief of staff who had already served Truman for two years as secretary of state, became defense secretary two days later, and on October 24, he announced the appointment of Kaufman Thuma "K. T." Keller as the "Director of Guided Missiles in the Office of the Secretary of Defense" to provide him "with competent advice in order to permit [him] to direct and coordinate activities connected with research, development and production of guided missiles." Keller would act as a "consultant and advisor" to the RDB, the Munitions Board, and other agencies in the Defense Department. Keller's new deputy, Maj. Gen. Nichols, had been Gen. Leslie Groves's deputy in the Manhattan Project and was at the time the top Pentagon official involved with nuclear weapons.[44]

Keller was one of the best-known business leaders in the United States at the time. He had been president of Chrysler Corporation since 1935, having succeeded Walter Chrysler in that job. He had spent nearly forty years in the automobile business, starting as a machinist on the shop floor at General Motors, where he worked for fifteen years, followed by a quarter century at Chrysler, where he became known for his abilities in expediting production. A few days after he took the missile appointment, Keller stepped down as Chrysler's president to become chair of the automaker's board. Keller took the missile job on a part-time basis, but he made lengthy visits to universities, government facilities, and contractor plants where work on missiles was being done.[45]

Keller's missile appointment had been in the works since at least August, and his name had been suggested by Truman, whom Keller knew from previous government service in wartime and in his administration in 1947 as chairman of the President's Advisory Committee on the Merchant Marine. On August 30, Keller and Louis Johnson went to the White House to discuss the job with Truman. As Keller later told Congress about their short meeting:

> President Truman outlined to me in general the work that was being done on guided missiles and how important he thought it was to the country, and that he

K. T. Keller, president of Chrysler (*left*), and William S. Knudsen, president of General Motors, shown leaving the White House in 1938. Library of Congress, Harris & Ewing Collection

thought there was a great deal of money being spent on it. He did not know whether we could make any savings. But he was quite sure that it could be moved along faster. And he asked me if I would undertake to do the work. At that time he said, "I think we should put our emphasis on defense missiles in particular" and suggested that maybe I would find out that there would be other missiles that should receive attention.

Keller told the president that he knew nothing about missiles but that he would look into the matter and let him know if he could help out, and Truman replied that Keller could do the job any way he wished.[46]

Keller's appointment as missile czar represents the one instance where President Truman took an active role in the missile program. In line with Neustadt's explanation that Truman's "instinct was to improvise arrangements around problems rather than to work through fixed procedures," his hiring of Keller as missile czar is a good example of improvisation, and one that was so effective that President Eisenhower and his own defense secretary were happy to continue the arrangement for several months.[47]

The Missile Czar

Keller served as the Department of Defense's director of guided missiles for nearly three years. When he began his work in the fall of 1950, Keller concluded that to organize the 15,000 people working on missiles into a single team would take between a year and eighteen months. Keller's staff was at first made up entirely of military personnel, starting with his assistant director, Nichols.[48] "I am a firm believer that defense should be part of our deterrence plan," Nichols wrote in his memoirs. "I worked hard to get the Nike 1 ground-to-air missile and also Air Force and Navy air-to-air missiles into production and established as a reasonable defense against airplane atomic bomb attack."[49]

Nichols and Keller began their work by visiting missile test sites. "Few missiles were ready for production. The first thirteen firings we saw all failed," Nichols explained. After Keller had studied the various missile programs and met with the responsible military managers, he set production recommendations, and then ensured that the service agreed in writing to the production goals that Keller and Nichols had set. When "three or four" programs reached this state, Keller and Nichols prepared a written report that was hand delivered to the president and to the secretary of defense or his deputy. Nichols then completed directives for the defense secretary's signature authorizing the spending of funds for the missiles. Nichols recalled that Keller never tried to stop a missile program he thought ineffective, but simply used his control of production funds to cause these programs "to fade away for lack of money," avoiding bureaucratic battles.[50] Keller said that the president and officials throughout the Pentagon "agreed that first priority had to be given to missiles intended to take aircraft out of the air," and that this had been the priority for some time before 1950.[51]

In July 1951, Keller prepared a report for the president and personally presented it in their only officially recorded White House meeting while Keller held the missile job. Keller estimated that 4,000 people in government and 11,000 contractor personnel were working on missiles, but he chose to keep existing organizations intact so as to not slow production. While many missile programs fell short of expectations, he decided that "an accelerated program of a few missiles that showed great promise was the most logical way of moving the program forward." Following the priority set by the military and the president for missiles to defend against Soviet bombers, Keller chose to accelerate production of the army's Nike and the navy's Terrier antiaircraft missiles, along with the navy's Sparrow air-to-air missile, which would also be used for aerial defense. Turning to offensive missiles, Keller spoke of two 500-mile-range winged missiles, the USAF Matador and navy Regulus, and the 5,000-mile-range USAF Snark as being put into limited production to advance their development. The accuracy of these missiles at distances from 100 to 500 to 3,000 miles demonstrated "promise that these weapons can be effective as atomic warhead carriers."[52]

In his formal report to the president, Keller stated that he found that the "highest priority had been assigned to air defense guided missiles. We have emphasized this priority." The Snark missile was being put in limited production to test guidance systems for missiles and to have a missile available in the short term for emergencies, he explained. "Development of a guidance system with sufficient accuracy and reliability is the crux of the problem for missiles in this field." He also mentioned that research and development was continuing for the long-range rocket-ramjet Navaho missile, which he called "the ultimate weapon that is being proposed in this category." He added that the navy's Triton long-range missile was continuing in research and development because missiles launched from ships often require "a different approach in the matters of storage, propulsion and guidance" from land-based missiles. Keller's report chronicled how missile costs were ballooning—he projected spending of $1.2 billion for fiscal years 1951 and 1952, with costs growing further in 1953.[53] In a letter to Truman in December 1952, near the end of Truman's term, Keller recalled the president's instruction to "produce something to knock the enemy airplanes out of the skies," and the result was that the Army's Nike antiaircraft missile was being brought into service two years ahead of schedule. "I can say that having the freedom of action that you gave me made it possible to get the kind of cooperation I needed from everyone concerned to get concentrated effort on these jobs."[54]

Keller had intended to resign when Truman left office in January 1953, but he agreed to remain when Eisenhower's incoming secretary of defense, Charles E. Wilson, the former head of General Motors, asked him to stay on. "I told him then that I would continue at least until June or July so he wouldn't have this problem of missile development suddenly on his hands while he was developing his organization and getting a line on his work," Keller wrote to the new president in a letter on May 12, 1953. Eisenhower responded two days later with a letter stating that Wilson "would very much like to have you retain control of the program for at least another six months."[55] Keller, Eisenhower, and Wilson met for lunch at the White House on June 16, 1953, where the president rebuffed Keller's proposal that Nichols be put in charge of missiles.[56] Keller's involvement with the missile program ended on September 17, 1953, and his work was transferred to the newly created offices of two assistant secretaries of defense.[57] In his final report, Keller wrote that "top priority as indicated by the JCS was for defense weapons."[58]

Keller's Legacy

Aside from expediting antiaircraft missiles like the army's Nike, Keller probably made his biggest impact on the development of army tactical missiles, particularly the Redstone intermediate-range ballistic missile, which was designed and built under the direction of Wernher von Braun and his German rocket team. Although Redstone ultimately had a range of only 200 miles, it played a key role in the early US space program. By the time the von Braun team began work on Redstone in 1951, the group had been relocated to the army's Redstone Arsenal in Huntsville, Alabama. In congressional testimony in 1957, von Braun explained that his work on the Redstone missile was greatly helped by Keller: "I would say, when he came in, things began to move. . . . Mr. Keller was the man who said, 'Let us build an operational ballistic missile.'" He added that Keller pushed almost too hard, given that the German team had done little groundbreaking work for six years when Keller began making resources available and "asking for the impossible all of a sudden."[59] The army reorganized its missile program following Keller's visit to the Redstone Arsenal in February 1951, and accelerated the Redstone missile according to what "quickly became known as the 'Keller' accelerated research and development program."[60]

Keller's success with the Nike antiaircraft missile no doubt earned him the army's further gratitude when the army won effective control of antiaircraft defenses and then defenses against ballistic missiles. Later versions of the Nike

missile were used for America's first missile defense systems, the Nike-Zeus missile in the 1960s and the Spartan missile used in the Safeguard missile defense system of the 1970s, which was closed down as a result of budget cuts and questions about its effectiveness. Antimissile programs gained prominence in the early 1970s, and again in 1983 when President Ronald Reagan launched his Strategic Defense Initiative. Antiballistic missile systems have remained a durable part of America's defensive system and political discourse since that time.[61]

During Keller's three years in office, spending on research and development for missiles rose from $159 million in fiscal year 1951 to $275 million in 1953, and total funding for missile procurement rose at an even higher rate.[62] Keller did a great deal to advance army and navy antiaircraft missiles, and the fact that these high-priority missiles had reached production helped build military interest in ICBMs. Aside from a small study that he ordered of Atlas, Keller and his office did little direct work to advance the ICBM. Interestingly, the Defense Department revived the position of director of guided missiles four years later in 1957 to expedite production of ICBMs and intermediate-range ballistic missiles.

Guided missiles occupied little of Truman's time and attention while he served as president, and so his record on missiles has not been widely discussed since he left office. One exception was during the political controversy that followed the Soviet Union's launch of Sputnik in 1957, when Democrats criticized the Eisenhower administration for moving too slowly on ICBMs, and Republicans fired back by accusing the Truman administration of doing nothing with missiles. Truman replied by invoking his hiring of Keller. The former president said he brought in Keller when he saw that missile programs were being slowed by interservice rivalry, and gave Keller instructions to "knock heads together" to break production bottlenecks. Truman also accused Eisenhower of quickly removing Keller simply because he was a holdover from the Truman administration, an accusation that was unfounded.[63] The post-Sputnik debate on Truman's role in missile programs had little relevance to the question of America's ability to match the Soviet R-7 ICBM because most missile programs during Truman's time in office were defensive in nature, and most contemporary experts in the field called for defensive missiles. The emphasis that Truman, Keller, and others placed on defensive missiles during that time has been ignored by most historical accounts of missiles in the postwar years.[64]

Eisenhower's appointment of General Motors President Charles E. Wilson to the position of secretary of defense, followed by Procter and Gamble President

Neil H. McElroy, and President John F. Kennedy's subsequent appointment of Robert S. McNamara, president of the Ford Motor Company, as his secretary of defense, have been suggested as representing a merging of the military and business elites of the United States. But this process had begun much earlier, when Franklin Roosevelt gave industrialists less prominent positions in the US government during World War II, and during the Korean War when Truman got a jump on Eisenhower by appointing Keller to the missile post, and then another Charles E. Wilson, the president of General Electric, to head the newly established Office of Defense Mobilization, which controlled resources, industries, and personnel needed for the Korean War and other defense needs.[65]

Conclusion

The year 1950 was an eventful period in the Cold War struggle between the United States and the Soviet Union, remembered especially for the beginning of the Korean War, the first important armed conflict involving the two superpowers following World War II. President Truman gave the go-ahead earlier that year for the development of thermonuclear bombs, which promised far greater explosive force than existing fission bombs. The year also saw Truman get involved in the issue of military missiles, which had been previously dealt with inside the military.

Although the army would continue trying to wrest control of long-range missiles such as ICBMs away from the air force through much of the 1950s, the USAF effectively won the struggle for control of these missiles in early 1950. The USAF would maintain control of strategic nuclear missiles delivered by bomber aircraft and long-range ground-based missiles into the twenty-first century. The effects of the interservice dispute over missiles was also felt outside the military in the US space program, as will be discussed in chapter 10.

The fact that defensive missiles had top priority in the years following World War II and through the Korean War was forgotten at the time of Sputnik in 1957, as Americans reacted to the fact that the Soviet Union had launched the first artificial satellite from earth and the belief that the Soviets were ahead in the race for an ICBM. The importance of defensive missiles during this time has also been ignored in histories of missiles and space launch vehicles. The emphasis Americans put on missiles such as Nike also showed that bomber aircraft remained the main priority and the main concern of the US military and others in authority, including President Truman. Although Truman's work

with K. T. Keller did little to expedite ICBMs, his 1950 decision to move ahead with thermonuclear weapons would later prove to be a turning point in the development of ICBMs. Before the importance of this new class of weapons could make itself felt, the concept had to be proven, and that would not occur until the Truman's final days in the White House.

7 The Revival of Ballistic Missiles

The changes affecting US military missile programs in 1950 were not restricted to the end of austerity budgets or the arrival of the missile czar in the Pentagon. During this time, the experts advising air force leaders on missile programs were changing their opinions on the kind of missile that would most effectively deliver nuclear weapons to an enemy target. Initial postwar studies of long-range missiles had suggested that winged missiles with jet engines would be best for the job. Even as the US Air Force's MX-774 rocket missile program was going through its death throes in early 1949, opinion among experts inside and outside the air force was beginning to turn in favor of long-range ballistic missiles. By 1951 and 1952, as expert opinion lined up behind ballistic rocket missiles, the pace of change proved to be too fast for some in the air force, who resisted calls for a major program focused on developing this type of missile.

The Soviet Union now possessed nuclear weapons, and Americans working to develop thermonuclear weapons did so amid concerns that the Soviets were seeking to build similar weapons. Defensive missiles had top priority in the early 1950s as fears grew of attacks from Soviet bomber aircraft armed with nuclear bombs as the Korean War continued with Chinese troops and clear evidence of Soviet support for the North Korean forces fighting US, South Korean, and other United Nations forces. While Soviet military missile programs were also making only modest progress owing to a low level of official support, this fact was not known outside the Soviet Union. But USAF and other experts thinking about the possibilities offered by long-range ballistic missiles realized that such weapons could soon be arrayed against the United States.

Looking at Ballistic Missiles

Col. Millard C. Young, chief of the air force's Guided Missiles Branch, estimated in January 1949 that solving the technical problems holding back long-range guided missiles would require spending between $1 and $2 billion in the money of the time, depending on the speed of development, and "the combined intel-

lects of the best scientists and engineers in the Nation." In a presentation on the USAF missile program to a Joint Chiefs of Staff committee, he added: "There is enough technical competence in this country to solve our longest term problem before 1960 if we are willing to provide the dollars." Young estimated that development costs for individual missile programs would range between $10 million for the least expensive missile and $150 million for the most expensive program. He believed that atomic bombs would only be carried in reliable delivery vehicles and that the "surest way to penetrate enemy defenses is by the supersonic surface-to-surface missile." Young predicted that to develop even a 1,000-mile-range supersonic missile to be ready by 1954 "would require an effort somewhat comparable to the Manhattan Project."[1]

A RAND Corporation series of missile studies for the USAF in the fall of 1949 urged that the USAF put a greater emphasis on rockets for long-range missiles than on ramjets. An extended study comparing rockets to ramjets for various ranges and payloads had found that rockets were superior for most payloads and most ranges, including very long ranges. RAND recommended that the USAF reevaluate its guided missiles program "with a view to accelerating research" for winged long-range rocket missiles, and added that research on winged ramjet missiles should continue.[2] James Lipp, the head of RAND's missile division, told the Research and Development Board that "Ram-jet missiles were superior for limited ranges, up to something in the neighborhood of 3,000 miles, and rocket powered missiles were superior for all ranges over 3,000 miles." RAND was therefore calling on the air force to "consider realignment of its relative emphasis on Ram-jet and rocket power plants."[3]

Despite the RAND findings, air force support for ramjets remained strong. The USAF Guided Missiles Branch recommended that the Navaho missile, which used a ramjet as the primary power source for its second and primary stage, "be continued at its presently planned rate" to ensure that a long-range strategic missile would be available. A ballistic rocket design had been rejected for Navaho because of the lack of data about aerodynamics at high speeds, the warhead reentry heating problem, and the guidance problem. Those three problems were not critical factors in Navaho's design, and "it was felt that a ramjet missile could be produced in less time than a rocket missile."[4]

The branch also recommended that the air force develop a winged missile similar to Navaho but with a rocket engine. A rocket "is less complex" than the two-stage system contemplated for Navaho, and rockets had greater potential than ramjets for higher speeds and longer ranges. "Based on other factors

such as reliability and vulnerability and empty weight, the rocket appears to be superior," but a high-speed rocket missile with a range of 7,000 miles would not be available before 1960, and only if problems in aerodynamics and materials to protect warheads could be solved. The branch called for the creation of an applied research program to obtain new information on high-temperature materials, including titanium and ceramic coatings to protect warheads, and on aerodynamics at high speeds that could be accomplished by using the navy's Viking rocket; the army's Bumper rocket, which used V-2 rockets as the first stage and a WAC Corporal rocket from the Jet Propulsion Laboratory as the second stage; or by reviving the MX-774 rocket, which had the benefit of being under air force control.[5]

Others inside and close to the air force defended the emphasis on ramjet research at the expense of more advanced missiles. Col. H. J. Sands, the Air Materiel Command Engineering Division's assistant for guided missiles, wrote in February 1950 that the division believed that the "ramjet range of speeds is about as far as we can go in the next ten years."[6] In September, Pat Hyland, an aircraft contractor manager who sat on the Guided Missiles Committee (GMC), wrote: "In my opinion no missile having a range of over 500 miles is likely to have adequate guidance for many years; hence these missiles should be given very reduced emphasis in view of the shortage of technical people." He added: "In my opinion no missile in the range 100 to 500 miles is likely to have adequate guidance for five years." Hyland recommended that short-range missiles be "developed and produced on a crash basis" and suggested cutbacks in longer-range missile programs, including the Navaho missile. Expressing concern about the availability of engineers, Hyland said: "The long-range missiles should definitely be restricted if a technical shortage is felt. In my opinion we should learn to walk before we run, and I am confident that experience and development in short-range missiles will contribute to the ultimate development of long-range missiles."[7]

Ballistic Missiles Return

Despite the technical and political problems facing long-range rockets and the troubled launches of the three MX-774 rockets, Convair did not totally abandon its work on ballistic missiles when the MX-774 program ended. In 1949 and 1950, Convair allowed Charlie Bossart to continue with nine paper studies of the technical problems facing long-range ballistic missiles, and he was allowed

Launch of the Navaho missile on September 11, 1958, from Cape Canaveral, Florida. US Air Force

to "borrow" members of his former MX-774 team to help with his studies, eight of which dealt directly with ballistic missiles and one with a ramjet-powered missile. During this time, Bossart and his colleagues devised two technical advances that were later incorporated into the Atlas missile: dropping off engines during flight and keeping the fuel tanks rather than dropping a whole rocket stage, and using small steering rockets for fine-tuning the missile's velocity

when the main engines stopped firing.[8] Even with a lack of government support, Convair hoped that this research would lead to a renewal of its military rocket work.

RAND's missile division had continued its extensive studies of surface-to-surface and air-launched missiles, and in 1950, a little more than a year after putting forward both winged ramjets and winged rockets as the main choices for long-range missiles, it stopped advocating for ramjet vehicles and instead called for low-altitude winged rockets and high-altitude ballistic rockets. This was a significant change, because now RAND was promoting vehicles of the type that would be used for the first ICBMs.

Late in 1950, RAND published a new set of findings on missiles in a set of nine reports. In a presentation in January 1951 to the Guided Missiles Committee, Lipp compared two different missiles projected to be built in 1960 carrying 8,000-lb payloads a distance of 4,000 miles. A two-stage ballistic rocket would reach an altitude of 500 miles, a speed of 15,000 miles per hour, just below the speed required to put an object in orbit, and fly for 24 minutes, slowing to nearly 10,000 miles per hour as it struck the target on the ground. A two-stage winged rocket would reach a speed of 10,000 miles per hour when its engines stopped firing, reach an altitude of 30 miles, fly for 40 minutes, and then hit the ground at a speed of 1,900 miles per hour. Lipp's plan anticipated separating the nose cone section from the rocket, leaving "a cone-shaped article containing the payload" to reenter the atmosphere. He estimated that the ballistic missile would weigh 1.3 million pounds, and the winged missile 180,000 pounds. Both missiles would be powered by a combination of gasoline fuel and liquid oxygen, representing a more powerful fuel combination than the alcohol and liquid oxygen combination used in the V-2 and the MX-774.[9]

Lipp explained that a ballistic rocket would be more reliable than a winged rocket because of a shorter flight time and simpler guidance equipment on board. He calculated that the winged rocket had a 50 percent chance of striking within 3,400 feet of a target with the technology predicted to be available in 1960, and the ballistic rocket had a slightly larger error. The ballistic missile would be less vulnerable to countermeasures than a winged rocket, and the winged rocket was one-third as vulnerable as a ramjet missile. While rocket engines large enough for the winged rocket were already being tested, larger rocket motors would be needed for the ballistic missile. The ballistic missile, however, would cost three times as much as the winged missile. Lipp concluded that the

winged rocket "has a very great advantage in flight economy; the ballistic missile has a moderate advantage in reliability."[10]

The air force supported winged missiles like the Northrop Snark and North American's Navaho because they appeared to offer more opportunity for ground control during early phases of flight than ballistic missiles did, and because their lower speed avoided reentry problems that arose from the lack of known materials to protect a warhead during reentry at high speeds from high altitudes. At the time, it appeared that ballistic missiles would simply burn up on reentry because there were no materials available to protect the missiles and warheads from the extreme heat encountered while returning from outside the atmosphere.[11] As shown by Lipp's presentation, ballistic missiles were believed to be far larger and significantly more expensive than winged missiles.

Despite growing questions about Navaho, the Air Staff issued a new military requirements document in August 1950 for Navaho, which called for a ramjet vehicle capable of carrying a Mark IV nuclear warhead 5,500 nautical miles at a minimum speed of Mach 2.75. In September, the USAF established a three-step development program for the missile that included a rocket booster that would carry the ramjet missile to speed and altitude before separating. The Navaho was to be available for use by 1958.[12] Air force officials running the Navaho program believed that a step-by-step approach to missiles was required, and so they defended the Navaho when RAND studies began to promote pure rocket systems as opposed to Navaho's rocket-ramjet combination.[13]

By the time Lipp made his presentation to the GMC in January 1951, he and his colleagues from RAND, backed up by Convair and its continued studies on ballistic missiles in 1949 and 1950, had convinced the Air Staff that active studies on ballistic missiles should resume. The removal of funding restraints that followed the onset of the Korean War undoubtedly also helped, with air force research and development funds more than doubling from $238 million in fiscal year 1950 to $522.9 million in 1951. On January 16, 1951, the Air Staff issued a new requirement to the Air Materiel Command for a "logical and effective program of development of a rocket type missile capable of accomplishing the strategic bombing mission," a description that fit what would come to be known as an intercontinental ballistic missile. The Air Staff specified a range of 5,500 miles, a minimum speed of six times the speed of sound over the target, and an accuracy that would have at least half the missiles striking within 1,500 feet of the target. The AMC allocated $500,000 in fiscal year 1951 funds for an initial

six-month study of problems associated with such a missile, followed by more intensive study of these problems, and it promptly issued a new contract to Convair on January 23, 1951, to pick up its ballistic missile work under Project MX-1593, which that summer became known as Atlas.[14]

Reorganizing Research and Development

As the fortunes of ballistic missiles were turning in 1949 and 1950, the USAF reorganized its research and development functions after receiving criticism of where they had fallen since Arnold had stepped down as US Army Air Forces commanding general in 1946. The reduced status of research and development in the USAF was symbolized by the fact that its top research and development post had been moved down from the Air Staff and into the Air Materiel Command in October 1947 when Curtis LeMay vacated the position. The Scientific Advisory Group that wrote *Toward New Horizons* had been transformed into a permanent Scientific Advisory Board, with von Kármán remaining as chair. But the air force made little use of the board, and in October 1947, shortly after the USAF was established, its leaders considered closing the board down. Some board members resigned because of its inactivity. But after von Kármán met USAF leaders in April 1948, the board's authority was restored, and in 1949, with the support of Gen. Donald L. Putt, the air force's new director of research and development, the board set up a working group under Louis Ridenour, the physicist and radar expert who had contributed to RAND's historic 1946 satellite study and by then a dean at the University of Illinois, to study research and development in the USAF.[15]

At the time that Ridenour and his group began preparing their report in 1949, the Hoover Commission on government organization had just criticized US military research and development. In September, the Ridenour report joined in the criticism, calling for restoration of the position of deputy chief of staff for research and development that LeMay had once held, along with separation of research and development from the Air Materiel Command. As a result of the Ridenour report and similar findings in November from a study run by the Air University, USAF Chief of Staff Gen. Hoyt Vandenberg ordered the restoration of the deputy chief of staff for research and development post in January 1950, and the creation of the Air Research and Development Command. In its early months of existence, the new command had to overcome resistance from the Air Materiel Command as it sought its own authority, and much of the time the new command continued to operate under the supervision of the AMC,

limiting its impact in the field of guided missiles. And after the Ridenour report was completed, the influence of the Scientific Advisory Board faded again until later in the 1950s.[16]

H-Bomb Progress

While RAND and the air force warmed to ballistic missiles in 1950 and 1951, other engineers and scientists were working to make thermonuclear weapons a reality. Months of setbacks and dead ends followed Truman's go-ahead to develop these weapons in January 1950, but the following year, Edward Teller and fellow physicist Stanislaw Ulam conceived of a new design for thermonuclear weapons that ultimately worked, using the gamma rays and x-rays generated by the fission trigger explosion to compress and superheat hydrogen isotopes through radiation pressure, forcing them to fuse into helium and leading to a massive release of energy. On November 1, 1952, the first thermonuclear device, code-named "Mike," exploded with a force of 10.4 million tons of trinitrotoluene (TNT) on the Pacific atoll of Eniwetok. The explosion packed more than eight hundred times the power of the atomic bomb that leveled Hiroshima. The Mike device weighed 82 tons, far too much for military use, because it used super-cooled liquid-fusion fuels. But smaller and lighter designs based on solid-fusion fuels were already in the works. The success of Mike was quickly brought to the attention of those working on long-range missiles for the air force.[17]

One of the major legacies of the creation of thermonuclear weapons was to prolong and deepen political divisions among scientists. The decision to remove Oppenheimer's security clearance in 1954 over his past associations with communists and his opposition to thermonuclear weapons was one of the central episodes in the 1950s involving the persecution of Americans associated with communism, and it tied the thermonuclear bomb to this dark chapter in American history. Teller, already controversial in scientific circles because of his difficult personality and efforts to take credit for advances leading to the thermonuclear bomb, sealed his notoriety in 1954 when he testified against Oppenheimer in the hearings that resulted in the former scientific director of Los Alamos losing his security clearance. In contrast, John von Neumann, a brilliant mathematician, computer theorist, and physicist who was involved in developing fission and thermonuclear bombs and who like Teller came to the United States after leaving his native Hungary to flee interwar anti-Semitism, refused to take part in the Oppenheimer hearings despite his own fervent anti-communism and support of the thermonuclear bomb.[18]

To many people, the thermonuclear bomb appears to be just a more powerful version of the fission bombs used in Japan in 1945. The thermonuclear bomb's far greater power and lighter weight, however, make it a distinct weapon from the fission bomb. Richard Rhodes, who wrote the most authoritative history of the thermonuclear bomb, noted that many of Teller's former colleagues from Los Alamos believed Teller had delayed its development far more than Oppenheimer ever did because of the way Teller directed research on thermonuclear bomb designs to favor highly powerful concepts. If smaller-yield devices on the drawing board in 1946 had been developed, the United States might have already had thermonuclear bombs on hand in 1949 when the first Soviet nuclear bomb was exploded. Instead, research focused on more challenging bombs with explosive power greater than a megaton of TNT, which turned out to be more "expensive, divisive, and dangerous."[19] One can also ask how such an alternative path for nuclear weapons would have influenced the development of delivery systems, including missiles and bomber aircraft.

Priorities for Missiles

Even though there was growing interest in offensive missiles, the 1951 research and development program approved by the Joint Chiefs of Staff in November 1950 continued to give top priority to antiaircraft missiles for all three services, reflecting growing concern about Soviet bombers. The list of eight air force priorities put the long-range Snark winged missile, which it called "interim," in sixth place and the Navaho long-range winged missile in seventh place. A list of missile programs that were supposed to be accelerated for operational use by July 1, 1954, included only antiaircraft missiles such as Nike and medium-range missiles for tactical purposes such as the USAF Matador winged missile. Navaho and Snark remained on the list of missile programs not slated for accelerated development, since they would not be ready for deployment by 1954 and because defensive and tactical missiles had higher priorities.[20]

During his time in office from 1950 to 1953, Defense Department Missile Czar K. T. Keller expedited defensive missiles but took little action on Atlas. Keller told Congress in 1958 that the Atlas missile "was purely in the state of discussion" in 1951, when he oversaw missiles. At that point, Keller brought in businessman, engineer, and astronomer Robert R. McMath as a consultant, and the only nonmilitary member of his staff, to help him assess Atlas. McMath and another expert went through "a wheelbarrow load of studies" on Atlas and concluded that more work needed to be done on the Atlas guidance system and

Launch of the Snark missile in 1956. US Air Force National Museum

the problem of warhead reentry through the atmosphere.[21] In a summary of missile projects at the time that he stepped down, in September 1953, Keller's list of missile programs in the research phase was headed by the Atlas, which Keller called a "highly complex and long term project still in its study stage."[22]

Convair Goes Back to Work

Despite its low priority, a ballistic rocket missile was back in development for the USAF starting in January 1951. Convair officially resumed its work on long-range ballistic missiles that had begun in the MX-774 program, this time under Project MX-1593, also known as Atlas. Convair's initial 1951 studies on the MX-1593 Atlas project, which examined both ballistic and winged rockets, were completed in September. The winged vehicle was shorter and lighter than the ballistic missile, but the USAF Air Staff decided to continue work only on the ballistic version of Atlas because it believed that it offered better performance

for cost. Convair pressed the existing argument that the winged version would be traveling slow enough that defenders could shoot it down near the target, while a warhead from a ballistic missile could not be shot down because of the extremely high speeds at which it would be traveling. Convair also questioned a supposed advantage of the winged missile, that it would require less heat protection because it was traveling at a much slower speed than the ballistic missile. Because the winged missile would remain attached to the warhead to the end of the flight, the entire winged missile body would require heat protection, unlike a ballistic missile warhead that could separate from its spent missile body before reentry.[23]

Convair's study of the ballistic version of the Atlas missile called for a gigantic rocket. The specifications for the 160-foot-high ballistic missile included the ability to carry a 4,500-lb atomic warhead to a target 5,500 nautical miles away at a speed greater than six times the speed of sound, and an accuracy requirement of at least one out of two hits within a radius of 1,500 feet of the target. The ballistic Atlas would be equipped with five engines, uprated versions of North American's 120,000-lb thrust rocket engine that it had developed for Navaho. A seven-engine version also on the drawing board would be able to carry a 7,000-lb payload. Such gigantic rockets came with price tags that matched the fears of those who questioned the sustainability of the defense spending required to support such weapons systems.[24]

Presenting the results of Convair's study to a meeting of the Guided Missiles Committee in May 1952, USAF Col. R. L. Johnston, chief of the Weapons System Division in the Air Research and Development Command, reported great promise for ballistic missiles: "Not only do these studies show that the program is technically practical but they also show that this method offers promise of being the most economical method of conducting strategic warfare. Also this weapon is the most invulnerable of any type under consideration and in fact in the future it may well be the *only* method of penetrating the enemies [*sic*] defenses." Turning to cost, Johnston argued that "when reliability, accuracy and vulnerability are considered, the rocket type missile is considerably cheaper" than bomber aircraft for conducting strategic warfare. He admitted that protecting the warhead from disintegrating in the extremely high temperatures encountered during reentry remained the biggest remaining technical problem.[25]

Following Johnston's presentation, the GMC approved the USAF's request to add the Atlas project to the list of approved guided missile projects in the

"Study Projects and/or Component Development" category. The USAF estimated that it would need to spend about $3 million for the Atlas project in fiscal year 1953 to continue studies, begin design of missile components, and initiate the fabrication of prototype missile systems.[26] In his report to the GMC, Johnston proposed that the USAF build a test vehicle with a speed close to that of the final missile. He added that the program would begin in "a fairly modest way" with component development work, followed the next year with building test vehicles. When GMC met again on August 21, 1952, it recommended that the USAF establish an "ad hoc group" to carry out further detailed study of Atlas.[27]

USAF Discord

Inside the air force, discussions were ongoing as officers in the Air Research and Development Command (ARDC) drew up proposed military specifications for Atlas in August 1952, including a warhead weighing only 3,000 lbs, an estimate that showed that word about advances in thermonuclear weapons had reached the air force. The specifications document went to air force headquarters on October 1, 1952, a month before the first test explosion would prove the concept of the thermonuclear weapon. At this time, differences over Atlas led to officers in the Air Staff in Washington refusing calls late in 1952 and early in 1953 from the ARDC to move ahead aggressively on development of the ballistic missile. Instead, the Air Staff decided to continue research and development on Atlas at a relatively slow pace. This was nearly the reverse of the situation in the late 1940s, but then the point of dispute between the Air Staff and other officers was over guided missiles in general, and now the dispute was over a proposed ICBM just as the technological obstacles that stood in its way were starting to fade.[28]

As a result of this dispute between the Air Staff and the ARDC, the USAF's Scientific Advisory Board set up a committee of experts known as the Ad Hoc Committee on Project Atlas, with eight members headed by Clark B. Millikan, the distinguished Caltech professor of aeronautics who was also chair of the GMC. In December, the committee visited the Convair, North American, and Bell Aircraft plants and was briefed by several relevant agencies before it submitted a report to the USAF on December 30, 1952. The committee unanimously agreed that the USAF "should retain in its program a project leading to the development of an intercontinental ballistic missile to carry an atomic warhead." More importantly, it also agreed that Atlas's accuracy and payload

characteristics should be "relaxed" to allow for a wider accuracy requirement of 1 mile and that Atlas's projected payload should be reduced to 3,000 pounds. The reason was what the committee's report called, vaguely, "anticipated developments in atomic warheads"—a reference to the new thermonuclear weapons that would be hundreds of times more powerful than existing fission bombs.[29]

And while the committee recommended that Convair remain as the prime contractor for Atlas, it opposed Convair's proposal to build "a very large test vehicle," and instead called for tests of guidance, propulsion, and reentry systems for Atlas using Navaho, Viking, and Snark missiles. The report concluded that it was still too early to set a date for completion of a prototype missile, but that the "Convair estimate of 1962 can be considered as a minimum date."[30]

The ad hoc committee met again in March 1953 to consider proposals from the ARDC for a more aggressive Atlas development plan and agreed to a new compromise development plan proposal that allowed testing to take place on test vehicles built by Convair, as ARDC wanted. The new plan also fit in with the Air Staff's plans for step-by-step testing of missile components following what an Air Staff official described as a "slowed down" budget scheme. While Atlas received a formal weapons system designation, it also had a relatively low 1-B program priority. The Air Staff approved the development plan that October.[31]

The bureaucratic foot dragging inside the air force criticized by political scientist Edmund Beard was clearly in evidence starting with the completion of Convair's Atlas study in September 1951, when the ARDC tried and failed to persuade the Air Staff to speed up work on Atlas. In August 1952, even before the crucial first test explosion of the thermonuclear bomb in November, experts in the ARDC began to estimate lower warhead weights, which would allow for a smaller ICBM that would be easier and far less expensive to build. The success of the test quickly led air force and other experts to begin believing the estimates of the thermonuclear bomb's far greater explosive power, which meant that the strict accuracy requirement imposed on missiles could be loosened. But the report of the ad hoc committee headed by Clark Millikan showed that differences over the technical problems facing ICBMs remained.

The air force was criticized in later years for putting too much emphasis on winged missiles during this time rather than ballistic missiles because of a perceived preference for winged vehicles, but that criticism failed to consider those experts outside the air force who also saw winged missiles as the design

of the future. The German rocket team envisioned winged missiles carrying warheads across the Atlantic Ocean, and this vision heavily influenced Theodore von Kármán in *Where We Stand* when he wrote of winged long-range rockets. Also, studies in the late 1940s and early 1950s about slowing down vehicles returning from earth orbit emphasized winged vehicles. The 1946 RAND satellite study spoke about winged vehicles coming back from space, and so did Wernher von Braun in a 1949 scientific paper and in a 1952 article in the famous series of articles on space exploration in *Collier's* magazine. While landing a warhead is different from landing a crewed spacecraft, clearly the emphasis on winged vehicles was not peculiar to the USAF.[32]

Intelligence on the Soviet ICBM

Another important question relating to the development of American missiles is how much the US government knew about what was going on with rockets on the other side of the Iron Curtain. The Soviet Union concealed its missile programs behind a shield of secrecy, which was deepened by its nature as a closed society. American policymakers, their frustration at Soviet secrecy fed in part by memories of Japan's surprise attack on Pearl Harbor in 1941, used spies, balloons, and aircraft in their efforts to learn what the Soviets were doing to develop missiles and other weapons. These ineffective programs led to the more useful U-2 reconnaissance aircraft and sophisticated signals intelligence programs that began after the Soviets had begun building their first ICBM. Probably the most important reason why Americans had little sense of Soviet plans for ICBMs was simply that the first Soviet ICBM did not officially win authorization until 1954. Before that time, work on the R-7 involved only a small group of engineers headed by Sergei Korolev.

On the American side, the first few years after World War II were a time of "disarray" for US intelligence services. Truman closed down the wartime Office of Strategic Services in September 1945, leaving intelligence in the hands of the individual armed services. In 1946, the Central Intelligence Group was set up, followed by the Central Intelligence Agency in 1947. But in its early years, the CIA was "understaffed, underfunded and a long way from its goal of synthesizing and correlating American intelligence."[33] There was little of the intelligence infrastructure that we take for granted today. The National Security Agency, which gathers electronic and signals intelligence, was not formed until 1952, for example. And the CIA's early attempts to recruit or deploy spies in the Soviet Union bore almost no fruit.[34]

Frustrated that so little was known about its Cold War adversary, the USAF flew aircraft along the boundaries of communist countries to test their radars and other defenses. In the late 1940s, the CIA and the US military launched high-altitude balloons from western Europe with cameras in the hopes that they would drift over Soviet territory for recovery near Japan. The plan failed. In 1950, Truman and the Joint Chiefs of Staff agreed to try more aggressive overflights of Soviet territory. Many flights returned information about military emplacements near Soviet borders, but much territory remained out of range, and several aircrews lost their lives. Aware of reports that the Soviets were launching missiles deep inside Russia at Kapustin Yar near Stalingrad, the Royal Air Force in cooperation with the CIA sent a specially equipped Canberra bomber over the area in 1953. The aircraft was nearly downed by Soviet anti-aircraft fire, and this near-failure ended aerial reconnaissance in Soviet airspace until the U-2 started flying in 1956. In 1955, the United States set up long-range radars and electronic signals listening posts in Turkey to gather information from Soviet missile tests.[35]

The lack of American intelligence on Soviet missile activity is also clear in once-classified documents relating to the work of the USAF and the Guided Missiles Committee of the Research and Development Board. In August 1947, the GMC discussed foreign intelligence information on Russian guided missile test ranges. "It is evident that little or no *direct* knowledge of work being done at Russian guided missile test ranges can be obtained," the GMC was told in a report that suggested that "proper evaluation of intelligence from widely separated fields, many apparently having nothing to do with guided missiles" may be needed to determine what the Russians were doing on their missile test ranges.[36]

USAF Maj. Gen. Earle E. Partridge, describing secret testimony in 1947 to the Finletter Commission, wrote: "The USSR appears to be conducting intensive research to produce surface-to-air guided missiles patterned after German developments, and in some measure in assembling and reconstructing German missiles." He wrote that there was "no specific intelligence" indicating that Russia was developing a long-range surface-to-surface missile, but "we can presume the Russians are working on a long range guided missile." Partridge suggested that Russian forces had made use of a larger number of German scientists than had American forces. Because of this, he wrote, Russia could be more advanced in guided missiles than the United States.[37] Industry witnesses to the commission expected that the Russians "had absorbed" German development tech-

niques for missiles, and their testimony suggested that the "Russians are probably further advanced than we are in these fields."[38]

On May 20, 1949, three months before the first Soviet nuclear test, a technical evaluation group submitted a report to the GMC based on briefings from the Joint Chiefs of Staff, the three services, and the CIA. The report projected that if war came in the 1950s, it would be a conflict of "extended duration" in which the Soviet Union would have strategic bombers comparable to the B-29 and guided missiles similar to German V-2 and Wasserfall antiaircraft missile by 1951–52. In fact, Soviet bombers and missiles with those capabilities were coming into service that year. Gordin, in his recent study of the effects of the first Soviet nuclear explosion in 1949, wrote of the dramatic growth of US intelligence estimates of the size of the Soviet nuclear stockpile in the months following the August 1949 explosion, along with larger estimates of the Soviet ability to deliver nuclear weapons with bombers. In November 1950, CIA analysts predicted that the Soviet Union would have 165 nuclear bombs by the middle of 1953. The actual number turned out to be probably less than 50. The growth contained in these figures no doubt bolstered the arguments of those who wanted to proceed with an American ICBM.[39]

President Truman had received a report in November 1949 from the CIA on Soviet flame and combustion research that could be applied to rockets and jets, which found that Soviet capabilities in this area "are clearly of a high order." The CIA found "substantial evidence" that this research was aimed at improving rocket and jet engines. These projects, according to the report, could increase the effectiveness of both defensive and offensive capabilities for the Soviet military.[40] A National Intelligence Estimate produced by the CIA in November 1950 on "Soviet Capabilities and Intentions" did not mention missiles. A special National Intelligence Estimate the following October on "Soviet Capabilities for a Military Attack on the United States before July 1952" estimated that the Soviet Union possessed V-1-type winged missiles with a range of 100 nautical miles that could be launched from ships or submarines.[41]

In December 1950, Fred Darwin, the executive director of the GMC, expressed his frustration about the amount of information available on Soviet missiles and bombers, saying the GMC "is being handicapped by insufficient technical intelligence information." He added that this problem "is further aggravated by the cumbersome and time-consuming methods now in use for bringing such meager information as is available" to the GMC. "This situation has made it difficult to assess the United States program in relation to that of the Soviet

Union and to insure that our program is properly focused," he added, complaining that some information was still being withheld from the committee, some of it from intelligence that was more than a year old.[42]

Two official histories of air force missile programs reported that in late 1951 and early 1952, the USAF had received intelligence reports suggesting that the Soviets had developed a rocket engine capable of generating 265,000 lbs of thrust, twice the power of any American engine, and that bigger engines were being developed. The reports in fact were incorrect, as the Russians experienced far greater difficulty than the United States in developing large rocket engines.[43]

In August 1952, the GMC convened experts at the Air Technical Intelligence Center in Dayton, Ohio, to discuss Russian missile programs. A presentation on propellant development noted that since the German technical personnel and facilities had been moved to the Soviet Union in 1946, large quantities of ethyl alcohol and hydrogen peroxide had been found at Khimki near Moscow, where rocket engines were indeed being developed, and that a liquid oxygen plant was under construction in the area. All these substances are useful as rocket fuels and oxidizers. Another paper stated that "100 V-2 power plants were manufactured at factory 456" between 1948 and 1950. A paper on guidance systems said, "captured Russian electronic equipment shows a marked improvement via German influence." A member of the GMC wrote that much more needed to be learned about Russian missile research because most information had come from German rocket experts who had worked in isolation in Russia, and none of them had information on what their Russian counterparts were doing. The report noted a lack of information on surface-to-surface ballistic missiles.[44]

In a congressional appearance in late 1957, Wernher von Braun testified that, at the time, he was given access to intelligence debriefings of German scientists who had worked in the Soviet Union and had returned to Germany in 1952 and 1953. "On the basis of these reports, I came to the conclusion that the Russians not only had made very poor use of the German talent they had taken along to Russia, but actually that there had been a lot of mismanagement of their program," which he admitted "proved to be entirely erroneous." When von Braun became an American citizen in 1955, he gained access to more classified information, including the fact that the Germans did not work directly with the Russian engineers. The Germans who worked in the Soviet Union, in his words, were "left completely in the dark about the fact that there was a Russian program outside of their own operation" and were "poorly used."[45]

In the background of the debates in the USAF and elsewhere in Washington about whether to build offensive missiles was the lack of information about what the Soviet Union was actually doing in this field. American intelligence agencies had hints of Soviet missile research, and these concerns were also driven by memories of the Japanese sneak attack that brought the United States into World War II in 1941 and the surprise that many people felt when the Soviet Union exploded its first atomic bomb in 1949.

Conclusion

As the MX-774 project came to an end in 1949, winged missiles such as Navaho appeared to air force leaders to offer the quickest way to a missile that could strike from intercontinental distances. But soon the ramjet-powered Navaho began to fall short of the bright future it once promised. RAND studies of missiles from 1948 through 1950 lowered the status of ramjet missiles and increasingly raised the need to develop ballistic rocket missiles. As the tight money policies restricting military spending ended with the start of the Korean War and ballistic rocket missiles looked more promising and feasible from a technical and expense standpoint, the USAF restored funding to Convair's work on ballistic rockets with the MX-1593 Atlas project. Despite this shift, ballistic missiles still faced hurdles including the guidance of the missile and reentry heating of the warhead. Atlas had only lukewarm support inside the USAF in 1952 just as more changes affecting missiles were about to be felt. American authorities inside and outside the air force were trying to make decisions on ballistic missiles with little sense of what their counterparts in the Soviet Union were doing.

As November 1952 began, the first test of a gigantic device proved the technology and the potential of thermonuclear bombs. Three days later, American voters elected a new president who would take office the following January. For the moment, the news of the powerful new addition to the nuclear arsenal caused air force engineers and leaders to take a new look at long-range missiles as a means of delivering nuclear weapons to far-off targets.

8 ICBMs Get the Go-Ahead

Major changes in the Cold War came in 1953. Gen. Dwight D. Eisenhower's succession of Harry S. Truman as president of the United States was followed a few weeks later with new leadership in the Soviet Union when Josef Stalin died. That summer, an armistice agreement brought the Korean War to an uneasy end. The thermonuclear bomb, first exploded the previous year by the United States, shook up the balance of forces between the superpowers, and then the Soviet Union followed up in August 1953 with a thermonuclear explosion of its own. Even as they were digesting the changes following on the thermonuclear bomb, officials in the US Air Force and America's aircraft industry got word of a surprising but promising solution to the problem of reentry heating of missiles and warheads. Along with concerns among American experts that the Soviet Union was already developing its own ICBM, these developments led to the USAF approving Atlas as a top priority program early in 1954. The Soviet ICBM program got its start at almost the same time when the Soviet government sought a means of delivering a thermonuclear bomb. While many accounts have highlighted the role of the Eisenhower administration in the decision to move ahead with Atlas as America's first ICBM, I argue that this decision was motivated by the creation of thermonuclear weapons, coupled with ongoing concerns about the possibility of Soviet strategic missiles.

The Eisenhower Administration

On January 20, 1953, Eisenhower became president, heading the first Republican administration in twenty years. During the 1952 election campaign, Eisenhower promised to institute reforms in the Department of Defense, a pledge he followed up on once in office. He proclaimed a "New Look" policy that sought to lower costs by reducing troop levels and increasing reliance on nuclear weapons and other new technologies. The big changes in defense affected military weapons development, including missile programs.[1]

Truman's outgoing secretary of defense, Robert A. Lovett, left a memorandum for the new administration that discussed what he saw as the deficiencies in his department. He called the Research and Development Board too rigid. Service members sitting on the board had to judge programs run by their own services as well as competing programs from the others. The new defense secretary, Charles E. Wilson, appointed Nelson Rockefeller, the future governor of New York and vice president of the United States, to head the Committee on Department of Defense Organization, which reported in April. The committee's membership included Lovett and Vannevar Bush, who both endorsed its recommendations to abolish the RDB and the Munitions Board and to take other measures to enhance the authority of the secretary of defense.[2]

By the end of the month, most of the committee's recommendations were transmitted to Congress as Department of Defense Organization Plan No. 6. During congressional hearings on the reorganization, Deputy Secretary of Defense Roger M. Keyes testified that the number of committees that had grown around the RDB was "nothing short of astounding" and required some people to do nothing but attend meetings. "In our recent studies of this problem, we found that the complicated board system was hindering rather than helping research and was proving to be an obstacle both to the services and to the scientists and engineers on whom we must depend," Keyes added. The new plan, which became law on June 30, strengthened the National Security Council and the office of the secretary of defense by giving them more authority, and it abolished the RDB, the Munitions Board, and other agencies in favor of six new assistant secretaries of defense.[3]

Donald A. Quarles, an engineer and physicist who had been a vice president at Bell Labs and president of the Sandia Corporation, which had a central role in developing nuclear weapons, was named assistant secretary of defense for research and development in September. The new secretary of the Air Force, Harold E. Talbott, had already named Trevor Gardner as his special assistant for research and development. Gardner, who was 37 at the time, had worked during the war on rocket and nuclear programs for the Office of Scientific Research and Development, and after that he became vice president and general manager of the General Tire and Rubber Company of California before starting his own electronics firm, Hycon Manufacturing Company. Gardner, who was known to be tough and abrupt, also had a reputation for getting things done. Wilson and Talbott put Gardner at the head of a committee that reviewed military

missile programs in the summer and fall of 1953. While the committee avoided thorny interservice issues, its recommendations led to new missile procurement procedures that required change after Keller's departure as missile czar in September.[4]

By then, Gardner was aware of the potential of the thermonuclear bomb. In March 1953, two physicists who were working on the new weapon, John von Neumann and Edward Teller, addressed an air force Scientific Advisory Board meeting at Maxwell Air Force Base in Alabama. Among those at the meeting was an air force colonel who was just a few weeks away from promotion to brigadier general, Bernard A. Schriever. Although Schriever was at the meeting to talk about a proposed bomber aircraft, he was intrigued by comments from the two scientists to the effect that a thermonuclear bomb weighing less than a ton and with the explosive force of 1 megaton of trinitrotoluene (TNT) would be possible by 1960. Such a bomb would have more than seventy times the force of the Hiroshima bomb and fifty times the power of the fission warhead originally envisioned for Atlas. Understanding that such a weapon would be a good fit for an ICBM, Schriever went to Princeton in May to obtain confirmation of this idea from von Neumann. Schriever soon informed the new assistant to the secretary of the air force for research and development, and twelve days after Schriever had gone to Princeton, Trevor Gardner himself made the trip to hear from von Neumann about the future of thermonuclear weapons.[5]

In his report on missiles that fall to Quarles and Talbott, Gardner recommended the creation of two committees—one to deal with strategic missiles and another for all other missiles. After overcoming resistance from the Air Staff, which wanted a review run by the air force's own Scientific Advisory Board, Gardner received the green light to form an independent eleven-member Strategic Missiles Evaluation Committee in October, with John von Neumann at its head. To provide technical support to the committee, Gardner considered the RAND Corporation, the Massachusetts Institute of Technology (MIT), and Caltech, but he rejected them because of their existing close relationships with the USAF. Gardner instead suggested Simon Ramo and Dean Wooldridge, who both had recently left Hughes Aircraft after having helped develop the Falcon air-to-air missile. They had formed a new company, the Ramo-Wooldridge Corporation. Both Ramo and Wooldridge joined the committee, and their company was contracted to provide support to the committee. Gardner later recalled that his remaining appointments to the high-powered committee were made

with the hope that committee members would be able to influence air force officers and others in the government who were skeptical of the ICBM.[6] Although RAND wasn't a formal part of the committee, it began work on a report of its own on strategic missiles.

Despite not being part of this review of missile programs, the air force's Scientific Advisory Board had formed a nuclear weapons panel headed by von Neumann. Gardner and Schriever called on it to provide further confirmation of the potential of thermonuclear weapons. The panel met between June and October 1953, and in a report to the USAF chief of staff in October, it backed up von Neumann's prediction of a lightweight thermonuclear bomb and called for a loosening of Atlas's accuracy requirements.[7]

Von Neumann's revelations to Gardner and Schriever were instrumental in his being named to chair the Strategic Missiles Evaluation Committee, which also became known as the Von Neumann Committee, and more popularly as the Tea Pot Committee, after its code name.[8] Committee member Pat Hyland later wrote that the committee split into three subcommittees, with one headed by Clark Millikan reporting on Snark, a second headed by Hyland reporting on Navaho, and the third headed by von Neumann reporting on Atlas. After Hyland and Millikan discussed Navaho and Snark at a meeting of the committee, Hyland recalled that von Neumann summed up in a "masterly fashion" and persuaded the committee that the Atlas was likely to have the greatest success.[9]

The Tea Pot Committee Report

The committee's report, which went to Gardner on February 10, 1954, highlighted major increases in the explosive power of nuclear weapons arising from new developments in the field of thermonuclear weapons, which meant that the degree of accuracy required of such missiles was no longer as great as it once was. Improved weapons meant that an ICBM might have to carry a warhead that weighed only 1,500 lbs, and that the accuracy requirement could be relaxed from a 1,500-foot accuracy requirement to "at least two, and probably three, nautical miles." While the report found that "available intelligence data are insufficient to make possible a positive estimate of the progress being made by the Soviets in the development of intercontinental ballistic missiles," it added that there was evidence of Soviet "appreciation" of these missiles and "activity" in the field. The committee report claimed that a Soviet lead in ICBMs "certainly cannot be ruled out." Based on von Neumann's strong beliefs about the

John von Neumann. US Department of Energy

danger presented by the Soviet Union, the report's original draft had contained stronger language about Soviet missiles. But faced with what Schriever's biographer Neil Sheehan called "sparse and inconclusive" information, the committee insisted on the compromise language quoted above. Von Neumann added a personal statement that warned of his "grave concern" about a Soviet lead in this field. The concerns about Soviet missiles were the main justification given in the report to go ahead with Atlas and continue the other missiles.[10]

The Tea Pot Committee complimented Convair on its work on Atlas, but it called for a "radical reorganization" of the organization that would build the ICBM "transcending the Convair framework." This new "development-management agency" for Atlas could set up a new development program within a year, leading to an "operational capability" within six to eight years. It also reckoned that the Snark missile should be continued as a "simplified" program and likewise that Navaho should continue with an emphasis on further

development of its rocket engine, which would be useful for both the Navaho and an eventual ICBM. Historians widely consider the Tea Pot Committee's report to be the true beginning of the Atlas program, and indeed of the US ICBM program. "What [Gardner] had essentially wanted was validation by these eminent scientists that an ICBM was technically feasible," Sheehan explained. "He got this and he got a great deal more."[11]

A RAND report written by physicist Bruno W. Augenstein and published on February 8, two days before the Tea Pot Committee report, reached similar technical conclusions. Augenstein had completed work on the report in November 1953 and had briefed top air force officers and the Tea Pot Committee on his findings in December. His report called for relaxation of "very severe performance specifications," including a reduction in warhead weight from 3,000 to 1,500 lbs, and a decrease in required accuracy from 1,500 to 3,000 feet, both changes owing to breakthroughs in thermonuclear weapon technology. If the ICBM program could get increased funding and a higher priority, he predicted that "an operational missile system of great value should be attainable before 1960," five years earlier than projected under the then existing plan. Augenstein noted that the warhead advances meant that the missile size could be reduced by 40 percent, thereby also reducing the severe technical challenges of designing a reentry body. The report also contained lengthy discussions of possible guidance systems and reentry vehicles: "The most important conclusion we have reached is that no technical obstacle is now foreseen which might prevent successful development of a long-range ballistic missile."[12]

Augenstein's report dealt with an issue that would later gain prominence, once the ICBM was under development: the need to preserve missiles for retaliation should an enemy attempt to win a nuclear war through a surprise first strike. He said that numerous measures could be taken to reduce the vulnerability of missiles on the ground, preserving a retaliatory force of missiles, including "dispersion, concealment, toughening of facilities, and use of mobile launchers." The air force would begin to build underground silos to protect ICBMs at great cost, but other schemes to protect missiles, including hardened silos and mobile basing, would come up later in the Cold War. Augenstein also mentioned the well-known fact that missiles would be difficult to intercept once they had been launched.[13]

A few days after he received the reports from the Tea Pot Committee and RAND, Trevor Gardner drew up a plan to accelerate the Atlas program. Gardner's plan envisioned spending $1.5 billion over the next five years, through

1959. In March, Gardner won endorsement of his plan from the air force's top commanders, who were spurred in part by concern that the air force could lose ICBMs to the army if they resisted Gardner's plan. On March 19, 1954, Air Force Secretary Talbott directed Air Force Chief of Staff Gen. Nathan F. Twining to proceed with Gardner's plan to build Atlas. The USAF had signed on to build America's first ICBM.[14]

Proof of the Breakthrough

The first confirmation of Teller and von Neumann's hypothesis that it was possible to quickly build a smaller thermonuclear bomb came in a series of test explosions in the Pacific known as the Castle tests, which included a thermonuclear bomb that was significantly lighter than the original thermonuclear device used in the Mike test because its solid fuel did not require the heavy equipment needed to lower the liquid thermonuclear fuel to cryogenic temperatures. The Castle Bravo shot on March 1, 1954, was nearly three times more powerful than predicted, and it became notorious because it contaminated a Japanese fishing boat and its crew. Along with further tests that went into May 1954, the Castle tests more than proved the design needed for lightweight thermonuclear bombs, and with it the feasibility of nuclear-armed intercontinental ballistic missiles.[15]

Air force generals Donald Putt and Bernard Schriever credited the new thermonuclear weapons with making ICBMs possible when they spoke to Congress in 1956—before the post-Sputnik controversy over ICBMs erupted—and after. In his 1956 testimony to a Senate subcommittee, Putt said that when the air force's ICBM work resumed in 1951, questions about the weight, size, and relatively small power of nuclear warheads at the time stood in the way of rapid ICBM development.[16] Schriever told the same hearings that the creation of thermonuclear weapons opened the door for ICBMs in what he called a "thermonuclear breakthrough." He testified that the limited explosive power of early nuclear weapons suggested that an ICBM would not be "a particularly useful military weapon" because it would require highly accurate guidance systems that were not available at the time and an extremely large missile. He repeated the statements in post-Sputnik testimony, estimating that a missile in 1951 would have to weigh a million pounds and have seven engines, compared to the three engines and weight of a quarter of a million pounds in the Atlas. The arrival of lightweight thermonuclear weapons, he said, made ICBMs feasible from the viewpoints of both technology and cost.[17]

Reentry Heating

Another of the more persistent technical problems standing in the way of an ICBM was the intense heating that a warhead undergoes as it reenters the earth's atmosphere on its way to the target. Tests by National Advisory Committee for Aeronautics (NACA) engineers on streamlined cone-shaped warheads showed that instead of cutting through the atmosphere and reducing heat inside the warhead, as some computer projections had suggested, the cones absorbed heat and melted under the strain. Test flights and wind tunnel measurements showed that the heat buildup in cone-shaped ICBM warheads at these planned speeds would destroy the warheads, and there was no known way to protect them. Early in the 1950s, the term "thermal barrier" had entered the lexicon of engineers working on ballistic missiles.[18]

A way to overcome the problem was finally found in the summer of 1952 with a counterintuitive idea from a rumpled, heavy-set aeronautical engineer at the Ames Aeronautical Laboratory of the NACA in the San Francisco Bay Area, not far from Stanford University. Harry Julian Allen, who signed his name H. Julian Allen but was known as "Harvey" by his friends, had developed a means of testing the behavior of bodies at up to fifteen times the speed of sound inside supersonic wind tunnels. "Half the heat generated by friction was going into the missiles. I reasoned that we had to deflect the heat into the air and let it dissipate," Allen recalled. The means he found to deflect the heat was the blunt body, which when it struck the atmosphere created a shock wave that absorbed and carried away much of the heat it generated in front of the blunt body. Allen briefed people involved in the ICBM program that September, and the following April, he and Alfred J. Eggers, also of Ames, authored a paper that remained classified for six years. Allen and Eggers's findings were incorporated into Augenstein's RAND report on Atlas. Hugh Dryden, who by then was the director of the NACA, said later that Allen's idea met resistance in the early months after his discovery. Although the concept pointed the way to new reentry vehicles, complex design work and testing with new equipment and rocket-launched reentry vehicles through the 1950s were still required to decide what shapes and kinds of materials would best shield the warheads. When Allen's discovery went public in 1957, Dryden argued that, along with the creation of the lightweight thermonuclear bomb, Allen's discovery converted the ballistic missile from "a practical impossibility to a virtual certainty." Despite the importance of this discovery, and the fact that reentry heating had

been raised on several occasions as a critical problem, Allen's discovery has not received anywhere near the same amount of credit from experts or historians as the creation of lightweight thermonuclear bombs for changing decision makers' minds in favor of ICBMs.[19]

Wings had been part of nearly all concepts in the late 1940s for long-range ballistic missiles and even human spacecraft. But Allen's discovery had the effect of removing wings from designs for ICBMs and most early human spacecraft. Although Allen's work with blunt bodies played an important role in knocking down an important technical obstacle to ICBMs, he and the NACA received little credit.[20]

Guidance

No similar kind of breakthrough was made in missile guidance systems in the early 1950s, although the Tea Pot Committee's easing of accuracy requirements reduced the problem. At the time, many people involved in the ICBM decision-making process supported radio guidance, where radio beams from ground stations are used to correct the missile's position, speed, and direction during the launch phase. Inertial guidance systems, where a computer uses inputs from motion and orientation sensors to determine the missile's position, speed, and direction, were still in an early phase of development in 1953 and 1954. Atlas D, the first operational version of Atlas, was equipped to use the Azusa radio guidance system. Even though Azusa performed well within specifications for accuracy, inertial guidance, which could not be jammed or dependent on the survival of ground facilities, gained favor for use in the Atlas E and F models and later missiles such as the Minuteman ICBM, after it was first used in the Thor intermediate-range ballistic missile.[21]

The Soviet ICBM

Von Neumann believed strongly in early 1954 that the Soviet Union was building an ICBM, but no one in the United States had any hard evidence on what was really going on with missiles behind the Iron Curtain. A National Intelligence Estimate three years later, in March 1957, on "Soviet Capabilities and Probable Program in the Guided Missiles Field," contained the following statement: "We have no direct evidence that the USSR is developing an ICBM, but we believe its development has probably been a goal of the Soviet missile program." The document projected that the Soviet Union would have a

5,500-nautical-mile-range ICBM ready for operational use by 1960 or 1961, and also stated, accurately, that the Soviet Union could orbit an artificial satellite in 1957. Much of this information had come from a U-2 reconnaissance aircraft that found the R-7 launch facilities at the previously unknown Soviet launch facility at Tyuratam in Kazakhstan. Later in 1957, after the launch of Sputnik, Eisenhower began receiving intelligence estimates that exaggerated the Soviet ICBM capability until photos from the U-2 and the first successful US military reconnaissance satellite in August 1960 showed the true state of the Soviet ICBM threat.[22]

It was only much later that the truth emerged about the state of the Soviet ICBM program in the early 1950s. Sergei Korolev's team and a group of mathematicians under the tutelage of Mstislav Keldysh, one of the top Soviet scientists of the time, had begun studies of more advanced missiles in 1951 and 1952, including ballistic missiles and winged missiles. Because Korolev had worked with aircraft in the 1920s before turning to rockets, he was alive to the possibilities of winged missiles, and his team designed a rocket-ramjet missile similar to the USAF Navaho. In 1953, Korolev shifted the winged missile work to two other design bureaus in the aviation industry so that he could concentrate on ballistic missiles. Boris Chertok, one of Korolev's top managers, wrote that Korolev's affiliation with the Ministry of Armaments dictated that he give preference to ballistic over winged missiles, which would fall under the separate aircraft industry. Both cruise missile projects continued until one was canceled in 1957 and the other in 1960, when ballistic missiles had carried the day and the Americans had canceled the Navaho program.[23]

Stalin gave little attention in his final years to the development of missiles, and instead focused on nuclear weapons and bomber aircraft. The relative priorities are demonstrated by the fact that nuclear weapons got roughly 14.5 billion rubles in funding, nearly seven times as much money as missiles received during the 1947–49 time period. The final months before Stalin died on March 5, 1953, saw him reduce his day-to-day supervision of military programs, and it ushered in a lengthy period of often haphazard change in the institutions and management that controlled long-range missile programs, reflecting the many changes in the Soviet leadership from Stalin's death until Nikita Khrushchev consolidated power in 1957. Stalin's death and the political changes it brought made 1953 a key year for Soviet missiles, just as the arrival of a new administration in Washington that year played a role in bringing America's ICBM program

to the fore. The Soviets exploded a low-power thermonuclear bomb in August 1953, and while the bomb was less advanced than American thermonuclear bombs of the time, this test opened the eyes of the new Soviet leadership to the potential of thermonuclear weapons.[24]

The new Soviet leadership was increasingly worried about its ability to mount an offense with nuclear weapons. It was aware of the progress the USAF Strategic Air Command was making with its powerful new bomber aircraft and emerging defenses against Soviet bombers around North America. The limitations of Soviet aircraft were also apparent to the Kremlin, which turned to the idea of long-range missiles. Andrei Sakharov, the brilliant Soviet physicist who became known as the father of the Soviet thermonuclear bomb and later as a champion for human rights, was asked to give a report that fall to a meeting of the Soviet Politburo estimating the weight of upcoming thermonuclear bombs, which the leadership wanted to mount on an ICBM being proposed by Korolev. Before the Politburo got Sakharov's report, Korolev obtained the cancellation of the R-3 missile program so that he could concentrate work on a true intercontinental ballistic missile. Sakharov based his report on a promising but ultimately unsuccessful concept, and estimated that the thermonuclear bomb would weigh 5 or 6 tons. In 1953, Korolev's bureau was forced to scrap its plan for a 3-ton warhead for their proposed ICBM and scale up the size and power of the rocket to carry the heavier warhead envisioned by Sakharov. This occurred at the same time that the US Air Force was reducing the size of the Atlas to carry a warhead weighing less than a ton. Based on the proposal of Korolev and his design bureau, the Soviet Council of Ministers approved giving Korolev the go-ahead to work on an ICBM that became known as the R-7. The R-7 won formal approval on May 20, 1954, a few weeks after the Atlas was approved in the United States following the report of the Tea Pot Committee.[25]

The Soviet path to approval of the R-7 ICBM between 1945 and 1954 was similar to the American path—official indifference until 1953, when military authorities realized the possibilities of the marriage of long-range missiles to thermonuclear bombs. Between 1945 and 1954, engineers from both superpowers had seen how German rocket experts had advanced rocketry during World War II with the V-2 ballistic missile. Building on captured knowledge and captured parts, American and Soviet experts slowly made advances in the technology needed for ICBMs until the arrival of thermonuclear weapons around 1953 prompted military and political leaders to allocate the resources they needed to build the first ICBMs.

Conclusion

The assumption of power by the Eisenhower administration and the creation of lightweight thermonuclear bombs gave the final impetus needed to get America's ICBM program fully under way in 1954. Of the two events, the thermonuclear bomb breakthrough was the most important because it convinced the two people who became champions of the ICBM in 1953 through 1955 and beyond—Trevor Gardner and Bernard Schriever—of the need to accelerate work on Atlas and other ICBMs. It also gave them the argument that persuaded others, including President Eisenhower, of the importance of ICBMs. Lightweight thermonuclear bombs vastly decreased the weight, size, complexity, and cost of ICBMs in one stroke, and they also reduced the need for pinpoint accuracy in reaching the target, eliminating a major technical problem. The success of NACA engineers in overcoming the warhead reentry heating problem has remained a relatively unknown but crucial technical advance that also helped make ICBMs a reality. The evidence linking the breakthrough in reentry heating to the decision to proceed with Atlas is not nearly as strong as the evidence tying the creation of the thermonuclear bomb to the go-ahead for Atlas, however.

The arrival of the Eisenhower administration led to a new Defense Department structure and to the appointment of people like Trevor Gardner, Harold Talbott, and Donald Quarles, who played important roles in promoting Atlas through the Tea Pot Committee. Support for the Atlas ICBM also came from leaders in the air force like Gen. Bernard Schriever, Gen. Donald Putt, and others who worked to overcome resistance in their service. What Schriever called the "thermonuclear breakthrough" was the crucial change that led the air force to begin serious work on ICBMs in 1954, if not to totally embrace them until the following decade. Atlas could have begun without the new administration, but it would not have started in the mid-1950s without thermonuclear bombs.

The decisive voices for the Atlas ICBM were the scientists and engineers who lobbied the air force and others in the government for this new weapon. At the top of the list of scientists was John von Neumann, and experts from RAND like James Lipp and Bruno Augenstein also helped turn the tide in favor of Atlas, along with the engineers and scientists who served on the Tea Pot Committee as well as the ad hoc committee on missiles set up in 1952 by the USAF Scientific Advisory Board headed by Clark Millikan, the chair of the Guided Missiles Committee of the Research and Development Board. The work of these experts built on earlier work, including that of Theodore von Kármán, Hugh Dryden,

and others in 1945 with the air force Scientific Advisory Group, who had to contend with evidence that major technical challenges stood in the way of ICBMs. Von Neumann was the most important scientific figure in creating support for the Atlas ICBM in 1954, not only because he chaired the Tea Pot Committee but also, perhaps more importantly, because he persuaded Schriever and Gardner of the possibilities for ICBMs opened by thermonuclear bombs. Von Neumann also articulated the fear that he and many of his colleagues had about possible Soviet missile programs. Von Neumann's part in the development of Atlas is arguably more important than that of any figure associated with the new administration such as Gardner or Quarles.

Before embarking on their own ICBM program in 1954, decision makers in the US government had little solid information on the state of Soviet missile programs. The major reason for the lack of evidence for a Soviet ICBM program in the late 1940s and early 1950s was that the first Soviet ICBM program did not officially begin until 1954. The main impetus for the initiation of the Soviet ICBM program was the creation of the thermonuclear bomb, just as it was for the American ICBM. Both superpowers looked to missiles out of concerns about the other side—the Americans about a possible Soviet ICBM and the Soviets about the American advantage in bomber aircraft. The truth about the development of Soviet missiles only became public after the end of the Cold War. Official Soviet accounts of the development of Soviet missiles suggested a rational development process guided by a wise leadership in the Kremlin.[26] Americans traumatized by the shock of Sputnik accepted the Soviet version of events, and this was reflected in the incorrect criticism of the Atlas ICBM starting long after work began on its Soviet counterpart, an idea that was reflected in historical accounts of Atlas.[27]

The thermonuclear bomb, first exploded in November 1952, arrived at such an early point in the development of nuclear-armed strategic forces that it decisively shaped them by making possible the ICBM and later the submarine-launched ballistic missile and even multiple warheads on strategic missiles, which first appeared in the late 1960s. These missiles, along with bomber aircraft, remain the central weapons of strategic nuclear forces to the present day. But even on the morrow of the Mike test, a great deal of work remained to be done on the thermonuclear bomb and on long-range missiles before they could be brought together in a new weapons system.

9 Deploying ICBMs

Within weeks of each other, the United States and the Soviet Union set to work on building their first ICBMs in the spring of 1954. When they began launching their missiles in test flights three years later, both countries experienced failures and problems, but the Soviets were able to conceal many of theirs. Once the early versions of their first ICBMs began flying, both the United States and the Soviet Union then had to construct the infrastructure to base these weapons, an activity that turned out to be much more expensive and complicated than expected. The limitations of ICBMs based on liquid-fueled rockets quickly became apparent, and these limitations affected deployment in the 1960s.

An examination of how the Atlas and its Soviet counterpart the R-7 were used for their primary purpose—as ICBMs carrying nuclear warheads—provides insight into how policymakers and later historians viewed these missiles. Both missiles were used only for a short period as weapons, and both wound up being used for a longer period as space launch vehicles. Both the Atlas and the R-7 were replaced as ICBMs by rockets that were better suited to the task of waiting for the moment when they and their deadly payloads might be launched.

Resistance and Reorganizations

The US Air Force's decision in March 1954 to proceed with development of the Atlas ICBM did not mean the end of resistance to the program. The commander of the Strategic Air Command, Gen. Curtis LeMay, who had long been associated with bomber aircraft, opposed Atlas because he expected it to fail or at best become a weapons system with poor dependability. Like Vannevar Bush, LeMay also questioned ICBMs because of their push-button nature, which he claimed made them a "space age Maginot Line." But other air force leaders who had not supported Atlas quickly began to cooperate with the program. After Air Force Secretary Harold Talbott directed USAF Chief of Staff Gen. Nathan Twining to accelerate the development of an ICBM on March 19, the USAF

established the Western Development Division in Inglewood, California, on July 1, and it soon began work under Gen. Bernard Schriever's command. At the same time, Assistant Defense Secretary Donald Quarles reconstituted the Tea Pot Committee into a more permanent group called the Atlas Scientific Advisory Committee. John von Neumann became chair of the committee, and six other Tea Pot Committee members also agreed to serve on the new committee, along with nine new members.[1]

The new committee and the air force had to grapple with the organization of the new ICBM development program, agreeing that fall on a controversial new management structure where the Ramo-Wooldridge Corporation would act as a "deputy" for the Western Development Division with responsibility for technical direction and systems engineering, on the condition that Ramo-Wooldridge not bid for other air force work as a contractor developing or building missiles or components. Convair won the airframe and assembly contract for Atlas rather than the traditional role it sought of prime contractor, and North American Aviation was contracted to build the engines. Ramo-Wooldridge's role in the management of Atlas was controversial but was later seen as a landmark in the advancement of systems engineering. Reflecting the Tea Pot Committee's views on the diminishing size of thermonuclear warheads, Atlas was designed to use only three large engines instead of the five or even seven that were mooted in 1951 and 1952. Nevertheless, at the height of Atlas development in 1958, more than 18,000 engineers, scientists, and others, along with 70,000 other people in twenty-two industries, worked on Atlas. The ICBM utilized 17 associated contractors, 200 subcontractors, and 200,000 suppliers.[2]

Trevor Gardner and Schriever believed that the ICBM was such a high priority that they sought and won the authority to simultaneously produce a second system to decrease the chances that the ICBM development effort could fail. This concept, known as concurrent development or concurrency, was also used in the Manhattan Project with uranium and plutonium bombs. Ultimately, concurrency led to the development of the Titan I ICBM.

In February 1955, President Eisenhower received a report from the Technological Capabilities Panel of the President's Scientific Advisory Committee, headed by Massachusetts Institute of Technology President James R. Killian, which warned of the possibility of a surprise Soviet missile attack on the United States. Among its many recommendations, the committee called on the president to give the highest priority possible to developing an ICBM and also called

for an intermediate-range ballistic missile (IRBM), and soon the army was creating an IRBM called Jupiter and the USAF Western Development Division was creating the Thor IRBM in addition to its work on Atlas and Titan I. That summer, Gardner and Schriever won the opportunity to brief the president on the ICBM program, and as a result of that briefing, Eisenhower granted "top national priority" status to the ICBM program, completing the work of assigning the top priority to Atlas that began in earnest with the Tea Pot Committee report.[3]

As the ICBM program progressed in 1956 and 1957, Truman-era management methods and problems reappeared. Despite Eisenhower's assignment of top priority status, Atlas and Titan had to contend with financial restraints imposed on defense spending in the months that followed, although these were exceedingly modest compared to the constraints placed on military spending by Truman in the late 1940s. The financial pressures on the ICBMs were deepened by the air force's decision to build the Thor. In a revival of the rivalry between the army and air force over missiles before the Korean War, Thor was locked in competition with the Jupiter IRBM, which was being built by the army with brief navy support. On November 26, 1956, Defense Secretary Charles Wilson issued a "roles and missions" directive that gave the air force operational jurisdiction over surface-to-surface missiles with a range greater than 200 miles and surface-to-air missiles with a range greater than 100 miles. The army won operational jurisdiction over missiles under those ranges, and the navy received operational jurisdiction over all missiles launched from ships. Wilson's directive handed control of IRBMs to the air force, but Army Ordnance took advantage of the problems that plagued Thor in 1957 in one more attempt to win control of IRBMs with its Jupiter missile. When the Thors began flying successfully, the army bid failed and both IRBMs were deployed under USAF control at launching sites in Europe and Turkey.[4]

In 1955, Wilson had also created a new Ballistic Missiles Committee to coordinate missile work among the services as the Truman-era Guided Missiles Committee was supposed to have done, appointed a special assistant for guided missiles, and upgraded the air force's ICBM Scientific Advisory Committee into a committee serving the whole military. In the fall of 1957, Wilson's successor as secretary of defense, Neil H. McElroy, revived the position of director of guided missiles, and William M. Holaday worked to expedite the production of missiles, starting with the Thor and Jupiter IRBMs, much as K. T. Keller had done at the beginning of the decade.[5]

ICBMs in the Cold War

The first Atlas flew on June 11, 1957, but it and the second Atlas in September failed early in flight. On August 26, the Soviet Union announced that its R-7 ICBM had successfully launched five days earlier, an achievement that followed two failed launches, the first on May 15. The R-7 launch in August was not as successful as advertised; the dummy warhead broke up in flight because the Soviets were behind the United States in realizing the need for blunt reentry bodies. While the Soviet announcement of its ICBM launch did not elicit a strong reaction from the United States, another R-7 launch a few weeks later on October 4, which orbited Sputnik, the first artificial satellite of the earth, did capture the headlines and set off a political controversy in America.[6]

A month after Sputnik was launched, a committee of eminent citizens organized by H. Rowan Gaither, president of the Ford Foundation, warned President Eisenhower of a Soviet lead in missiles, complete with a description of the situation as a national emergency, and called for increased spending on missiles, dispersal of bomber aircraft, and other measures, findings that weren't surprising given that one of the report's main authors was Paul H. Nitze, then a former State Department official who in 1950 had written NSC-68 for Truman, a document that heralded the beginning of the Cold War military buildup. Eisenhower, who by then had access to information gathered by U-2 reconnaissance aircraft over the Soviet Union, disagreed with many of the Gaither Committee's findings, but the leaked highlights of its top secret report began appearing in newspapers in December, increasing the pressure on the president. Another blue-ribbon panel sponsored by the Rockefeller Brothers Fund issued a similar report in January 1958 echoing the Gaither Committee's findings.[7]

During the political controversy that followed Sputnik, Democrats sharply criticized the Eisenhower administration for the Soviet successes in space and apparent lead in ICBMs, notably through Senator Lyndon Johnson's Preparedness Subcommittee of the Senate Armed Forces Committee, which held highly publicized hearings on the matter. Republicans responded to the criticism by blaming the Truman administration for the United States' late start on ICBMs after the cancellation of Convair's MX-774 contract and Truman's impounding of $75 million of appropriated research and development funds in 1947 as part of his economy drive. "As late as 1952 we were spending less than a million dollars a year" for both ICBMs and intermediate-range ballistic missiles, one Republican member of Congress falsely charged.[8]

Launch of the Atlas 10A, an Atlas A rocket, from Cape Canaveral on January 10, 1958. US Air Force

On December 17, 1957, the third Atlas launch was successful, but this achievement was obscured by the reaction to Sputnik and the second Soviet satellite in November, which carried a dog into orbit, along with the US Navy's failed attempt to launch a Vanguard satellite on December 6. The initial Atlas missiles were not equipped to fly the planned full range of 5,000 nautical miles, and it was not until August 1958 that an Atlas flew all the steps necessary to complete its full range. Further successes, including the lofting of an Atlas fuselage into orbit late that year with a device that broadcast a Christmas message from President Eisenhower, were followed by failures in 1959 during flight tests of the operational version. Eventually the bugs were worked out, and in

September 1959, a year later than Trevor Gardner had hoped, the first battery of Atlas D missiles went on operational duty at Vandenberg Air Force Base in California.[9]

In the months following Sputnik and other widely publicized Soviet space successes, Soviet Premier Nikita Khrushchev boasted that his government was turning out ICBMs "like sausages." But the truth was that the R-7 was difficult to assemble and launch, and was as unsuited to be an operational ICBM as it was suited to be an effective launch vehicle for satellites and space probes. It had been designed to launch 6-ton payloads rather than the smaller warheads of the Atlas and Titan. The R-7's properties were a direct result of the Soviet leadership's decision in 1954 to begin building their ICBM based on Sakharov's incorrect estimate for the weight of a thermonuclear bomb. But the R-7's prowess as a space launcher gave the world the illusion that it was far superior to Atlas as a weapons system and was ready for use first, when in fact Atlas was more effective and put America well ahead in the race to develop an effective ICBM system. Only six R-7s could ever be put on alert at one time because there were only six of the gigantic R-7 launch pads, and Soviet ICBMs therefore fell far behind America's missile force until another Soviet design bureau succeeded in developing a rocket better suited to be an ICBM. It came into service starting in 1962. Khrushchev and the Soviet leadership received an expensive and unwelcome introduction to the complex questions relating to missile basing, procedures for launching them, and strategic questions about their use in 1958, when the construction of launch pads at Plesetsk in northern Russia fell well behind schedule and over budget. After a furious Khrushchev was talked out of canceling the construction project, he halted further plans for deployment of the R-7 and pressed for new ICBMs that would require smaller launch pads. The Soviet leadership, realizing that there were limits to how long its forces could conceal missile launch sites, supported building underground silos for the newer and smaller missiles.[10]

The Soviets were already well behind the Americans when it came to serious work on protecting their missiles. The USAF had already decided in 1955 to base its ICBMs in hardened sites and later in silos to protect them against a Soviet preemptive strike, although the first Atlas ICBMs were based above ground. As Jacob Neufeld detailed in his history of ICBMs, the new Atlas and Titan bases arose from some of the largest construction projects of the time. The fact is that basing missiles is an integral and expensive part of building the technological system created around ICBMs. The complexities involved in the design, con-

struction, and operation of Atlas and Titan missile silos caused many headaches for the USAF, particularly because of their size and issues related to fueling the missiles with supercooled cryogenic fuels. After the completion of the Titan I, a new Titan II missile was designed and built. Titan II marked an advance on Atlas and Titan I because it was fueled with hypergolic liquids that could be stored in the missile at room temperature. But these fuels had storage limitations because they were extremely corrosive. The Strategic Air Command also had to train crews to maintain, fuel, and launch all these missiles. These problems delayed full deployment of Atlas missiles into 1962.[11]

The mundane problems of launching ICBMs were only a part of the many complicated issues that had to be solved to make the new ICBMs effective as weapons systems. It was only in the late 1950s that academics at RAND and elsewhere began to think seriously about how to fight wars with missiles, including addressing questions related to protecting missiles in silos, submarines, and elsewhere against a surprise first strike by the other side, creating antiballistic missile defenses, and considering how and when to use ICBMs in the face of a missile attack by an adversary. Later, missiles carrying multiple warheads and devices designed to confuse defensive systems about the location of warheads were deployed.[12]

Following the initial success in 1960 of America's first military reconnaissance satellite, Corona, the US military began launching satellites with mapping cameras and other equipment to facilitate precision targeting for bombers and ICBMs. This mapping work relates to another part of the targeting problem that bedeviled bombers and missiles in the early years of the Cold War. Even if bombers and missiles were equipped with guidance systems capable of delivering warheads extremely close to their targets, they would be of limited use if the location of the target wasn't known exactly. The US military lacked good maps of much of the Soviet Union in 1945, and many targets of interest, such as military bases and factories, were located in these poorly known areas, a problem that was eventually solved by aerial and satellite reconnaissance and mapping in the late 1950s and the 1960s. Because of the great distances involved, ICBMs and bombers had to account for the exact shape of the earth and variations in the earth's gravity field over its surface. The earth's dimensions affect the distance a missile would have to travel to a target, and gravitational variations affect the path of a missile. Although some academics had begun working on these problems in the early 1950s, tracking of the first artificial earth satellites such as Sputnik, Explorer, and Vanguard gave dramatic evidence that the earth

wasn't a perfect sphere and had gravitational variations. The US military underwrote the creation of academic studies in geodesy at Ohio State University and elsewhere, and launched satellites that improved our knowledge of the exact shape of the earth to improve missile targeting. The military work on geodesy also saw a degree of competition between the army, navy, and air force. The need for sophisticated mapping and geodetic work shows that the creation of an effective ICBM system involved far more than the missiles themselves.[13]

Even as Atlas, Titan, and Thor were undergoing testing in the late 1950s, the USAF and the US Navy were hard at work exploiting recent advances in solid fuels for rockets that allowed them to build a new generation of long-range strategic missiles. The navy successfully launched the first Polaris two-stage solid-fuel missiles from submerged submarines in 1960, debuting a new weapon that became a key part of America's nuclear deterrent that exploited the fact that submarines moved and were difficult to track. In October 1962, the air force began to deploy Minuteman solid-fuel ICBMs, which were far more suitable to the task than Atlas or Titan because they were smaller, fitting better inside protected missile silos. More importantly, because their fuel was solid and thus permanently loaded on board, Minuteman missiles did not require the dangerous and complicated fueling operations of liquid-fueled rockets and could be launched instantaneously at any time. They could also be deployed in much larger numbers than Atlas and Titan. Minuteman missiles were quickly shown to be more effective than Atlas and Titan because they were much easier to keep on alert. For these reasons, Minuteman won the support in 1958 of Curtis LeMay, by then the air force vice chief of staff, that he had withheld from Atlas. The Soviets did not field a similar missile for several more years. Minutemen missiles have not been used to launch satellites into orbit.[14]

Although the difficulties the USAF faced in building launch pads, missile silos, and other infrastructure for ICBMs were not secret, they were not widely publicized. The Soviet problems with missiles were kept secret by both sides for some time, and detailed information did not become public until the end of the Cold War. The idea that the Soviets had the first effective ICBM with the R-7 must be reconsidered in the face of its weaknesses as a strategic missile. As well, the Atlas's drawbacks as an ICBM must also be considered when assessing the resistance shown to it by LeMay and other USAF leaders.

As for the Navaho missile, the air force had canceled it in 1957 but allowed tests to continue through 1958. The Navaho left as its major legacies its rocket engine, new alloys for its skin, and its guidance system, which were used in

Atlas and other ICBMs. The Kennedy administration canceled the subsonic Snark in 1961, just two years after it was first made operational.[15]

In 1960, Americans incorrectly believed that America's ICBM program was behind the Soviet Union's program, and so missiles became a political issue in the presidential election that year. John F. Kennedy accused his Republican opponent, Vice President Richard M. Nixon, and President Eisenhower of allowing a "missile gap" to develop. In 1960, photos from the first successful American Corona reconnaissance satellites backed up the U-2 photos showing Eisenhower that the Soviet lead was an illusion, but he did not make the results public for fear of having to reveal this new and powerful intelligence tool. It was left to the Kennedy administration to begin to tell the truth the following year. As Kennedy's secretary of defense, Robert McNamara, admitted shortly after taking office in 1961, "If there was a gap, it was in our favor." America's advantage in strategic nuclear forces was driven home the following year.[16]

The greatest nuclear confrontation of the Cold War took place in October 1962 when the Soviets tried to challenge America's nuclear advantage by placing medium-range ballistic missiles just off the American coast in Cuba. At that time, the Americans were capable of delivering 4,000 nuclear warheads, mostly with bombers, including 179 warheads on ICBMs and at least 112 on submarine-launched ballistic missiles (SLBMs). The Soviets could hit back with only 220 warheads, including 20 on ICBMs. In the years following the Cuban Missile Crisis, the United States continued to build up its forces, but the Soviets were determined never to be caught short again, and worked even harder to match its adversary until missile forces reached an uneasy equilibrium that lasted for the final two decades of the Cold War.[17] The United States' strategic nuclear forces, the technological system designed to deliver the US military's strategic nuclear weapons to targets in the Soviet Union during the Cold War, constituted the "triad" of ICBMs and bombers from the USAF and the navy's force of nuclear-powered submarines carrying ballistic missiles such as Polaris and later Trident.[18]

At the time of the Cuban Missile Crisis, the first Minuteman missiles came into service, and before the end of 1962, the final Atlas ICBMs were put on alert. The Atlas ICBMs did not remain in service for long; most were removed in 1964 and 1965. In the years that followed, America's ICBM force was composed of Minuteman ICBMs complemented with some Titan IIs. Some advanced versions of Minuteman remain in service today.[19] Kennedy and his successor, Lyndon B. Johnson, built up missile forces based on Minuteman ICBMs and Polaris

Gen. Bernard Schriever and the Atlas ICBM. US Air Force National Museum

submarine-based ballistic missiles. Missiles remained in the forefront of Cold War debates in the decades that followed, especially after new Soviet ICBMs came on line in the late 1960s that gave the Soviet Union parity in that field with the United States, a parity that remained in place through the end of the Cold War in 1991.[20] Cold War–era hawks in the United States such as Paul Nitze raised concerns about growing Soviet military power in the 1970s, including ICBMs and SLBMs equipped with multiple warheads. When Republican Ronald Reagan took office in 1981, he pursued a new American military buildup,

including advanced new missiles and bombers and a renewed support for antiballistic missile systems that continued through the end of the Cold War.[21]

The monetary cost of the Atlas ICBM has been variously estimated at $42 billion and $47 billion in today's currency. In 1965, historian Ernest George Schweibert put forward a figure of the equivalent of $120 billion today for the Atlas, Titan, and Minuteman ICBM programs from 1951 to 1964, including infrastructure. Another estimate put the entire cost of the three programs up to 1996 at $219 billion in today's currency. The cost of the air force program to develop ICBMs was certainly comparable to the Manhattan Project, which would cost $27 billion today. The final price tag for Atlas was significantly larger than any missile developed to that time and outstripped all cost estimates made in the late 1940s.[22] The continued use of ICBMs also involved many other costs, including highly expensive research and development of newer generations of the missiles themselves, and the costs associated with their continued deployment around the United States.[23] Large amounts of money have been spent to create systems designed to protect against ICBMs, despite ongoing questions about whether these systems can work. The additional costs also include the creation of the wider infrastructure for America's nuclear forces and for the national security state.

Scholars have argued about the impact of the great expense and size of America's strategic forces, a controversy fueled by Eisenhower's warning in 1961 about the power of the "military-industrial complex."[24] Aaron L. Friedberg, an international relations specialist, has argued that America's nuclear forces and the policy of deterrence that underlay them prevented the United States from becoming a garrison state because they were actually less expensive than other strategic alternatives involving larger conventional forces, which among other things would make larger demands for military recruits.[25] Historian Alex Roland, on the other hand, called the post-Sputnik controversy a key episode in the campaign of US military and industrial interests for "more and better weapons, expansion of roles and missions, and mobilization of the civilian economy in the service of the state."[26]

Conclusion

The first flights of ICBMs in 1957 were widely and incorrectly seen as marking the beginning of the ICBM as an effective weapon. Even when America's first Atlas ICBMs were put on alert in 1959, the ICBM formed an insignificant if expensive part of the US nuclear arsenal. Those first Atlases stood on launch

pads in the open, and they required extensive preparation before they could be launched. Even though silos were soon built to protect Atlas missiles, America's ICBM force didn't really become effective until the mid-1960s, when Minuteman missiles, which were ready for nearly instantaneous launch around the clock, became the center of America's ICBM force. In the 1960s, work continued to improve missile guidance systems, along with the equally important work of establishing the exact locations of targets in the Soviet Union, and where they stood in relation to the missile launch pads in the United States.

The nuclear-armed ICBMs deployed by the United States and the Soviet Union became a central fact of the Cold War and have remained on alert since then, albeit in reduced numbers. These nuclear-armed missiles have been widely credited with deterring the two superpowers from engaging in a direct war. Cold War historian John Lewis Gaddis and others have written extensively about nuclear deterrence through the Cold War, as well as the role of reconnaissance satellites, which this study argues have been an important part of ICBM infrastructure, in maintaining that deterrence.[27] Nuclear arms historian Richard Rhodes wrote at the conclusion of his 2007 book *Arsenals of Folly* that both sides in the Cold War based their planning on the assumption that the other side would strike first with nuclear weapons, even though both sides shrank from a first strike because of the consequences. He pointed to a study by political scientist Jacek Kugler questioning the effectiveness of nuclear forces in deterring the escalation of confrontations between nuclear states and other states. Instead, the United States has been saddled with the heavy costs of becoming a national security state, costs that continue to the present day. Those costs not only involved large sums of money but also freedom of belief and expression, as J. Robert Oppenheimer and others learned when they came under attack in the 1950s for their opposition to thermonuclear weapons, which was seen as an attack on the national security state itself.[28] Atlas and other ICBMs armed with nuclear weapons changed warfare between the superpowers during the Cold War by making a direct military confrontation unthinkable, as many historians and other experts have concluded.[29]

10 The Space Race

When the Soviet Union launched the first artificial earth satellite atop an R-7 ICBM on October 4, 1957, the news surprised many Americans despite many Soviet announcements of pending satellite plans in the preceding months. The orbiting of Sputnik created what leading American scientist James R. Killian called a "crisis of confidence" over national security, space exploration, and the state of education in the United States.[1] The creation of this crisis was rooted in part in the mistaken but widespread belief that a rocket capable of sending a satellite into space was automatically a weapon that could carry nuclear weapons anywhere.

Both the Atlas and the R-7 rockets saw dual use as space launch vehicles and as ICBMs, but both had serious limitations as ICBMs, especially the R-7.[2] Atlas's place in the history of spaceflight is complicated by the fact that the United States and the Soviet Union went about the business of launching their first satellites in differing manners, using different types of rockets. The confusion between space launch vehicles and nuclear weapons carriers that created the Sputnik crisis led to many myths that have outlived the Cold War. These myths have misled many people about the beginnings of the space race of the 1950s and 1960s that climaxed with the first human footsteps on the moon, and about the roots of Atlas, America's first ICBM. This book concludes with a brief examination of Atlas's place in the space race to further clarify its history and the myths that have surrounded that history.

Sputnik

Officially, Sputnik and Vanguard had their roots in the International Geophysical Year (IGY), an eighteen-month period of intense worldwide scientific activity that took place in 1957 and 1958. Scientists began organizing for the event in 1950, and shortly after the 1955 White House announcement that the United States planned to launch an artificial satellite of the earth during the IGY, a Soviet official announced that his government would also launch a satellite.

Historical research of once-classified records has uncovered the fact that Eisenhower administration officials were already looking forward in 1954 to building satellites that could look down on the Soviet Union and photograph military installations, but they were concerned about whether they could establish the right of overflight for these satellites. No such right existed for aircraft. A committee tasked by President Eisenhower to study the possibility of a surprise attack on the United States completed a report in March 1955 suggesting that the United States launch a small scientific satellite to establish "freedom of space" for future military reconnaissance satellites. The recommendation was quickly backed up by the National Security Council, and, fortuitously, the government had also received a recommendation by scientists preparing for IGY that the United States build a scientific satellite. With support from the defense and state departments, the White House announced on July 29, 1955, that the United States would launch scientific satellites as part of IGY.[3]

The Soviet government had not decided on launching a satellite at that time, but a leading Soviet scientist, Leonid Sedov, told a scientific conference in Denmark four days later that a Soviet satellite was possible within two years. While Sedov wasn't speaking officially, supporters of spaceflight such as Sergei Korolev were working to encourage the Soviet leadership to allow them to use an ICBM to launch a satellite. As part of that campaign, the Soviet Academy of Sciences had announced in April 1955 the creation of an interplanetary commission, and the National Security Council quoted this announcement in backing up its recommendation to Eisenhower that the United States proceed on a satellite program. Korolev and his colleagues continued to lobby for a Soviet satellite, and finally, in January 1956, the Soviet Council of Ministers approved a satellite program. Soviet designers began work on a satellite containing numerous scientific instruments, but as the designers encountered a series of problems, the US Army launched an upgraded Redstone missile with extra stages called Jupiter C in September 1956. The dummy payload reached a record altitude of nearly 1,100 km. Korolev and his team saw the test as an attempt to launch a satellite, and their concern about this launch prompted them to change their plans and begin building a much simpler and smaller satellite than they had originally planned.[4]

Korolev successfully pushed to use the R-7 ICBM his team was developing to launch the first Soviet satellite, but Schriever and USAF leaders deliberately avoided offering Atlas for use in early US satellite programs until their missile was proven in 1958. The work of launching America's first satellites was there-

fore left to much less powerful rockets like the army's Redstone missile and the navy's purpose-built Vanguard satellite launch vehicle.[5] The Soviet R-7 ICBM was better suited than any American rocket of the time, including Atlas, for launching large payloads into space, and after the R-7 had proven itself in two successful test launches, Korolev received the green light to use it to launch the first Sputnik on October 4, 1957. After the unexpectedly rapturous worldwide reaction to Sputnik, the Soviet leadership encouraged Korolev to use the R-7 to launch other satellites and space probes. So the Soviet Union also used the R-7 to launch Sputnik 2 with a dog on board in November 1957, followed in 1959 by the first probes to strike the moon, photograph its far side, and enter solar orbit.[6]

"Sputnik was a sharp slap to American pride, but worse, it suggested Soviet technical and military parity with the West, which in turn, undermined the assumptions on which the free world defense was based," historian Walter A. McDougall explained.[7] Propelled in part by fear of Soviet nuclear weapons and ICBMs, American politicians and the media compared Sputnik to Japan's 1941 sneak attack on Pearl Harbor and supported various schemes—including a more aggressive space program under a new civilian space agency, NASA, and increased federal spending on education—to restore America's pride. Americans had to contemplate for the first time the reality of a highly destructive weapon in foreign hands that could easily overcome the protection afforded by America's location in the Western Hemisphere. The fact that the supposedly technically backward Soviet Union had launched the space age rather than the United States added humiliation to the fear many Americans felt, and they soon were asking how the Soviets beat the United States to the first launch of an ICBM and of a satellite.[8]

Even as the new Kennedy administration entered office in 1961 with private reassurances about the relative position of the superpowers' nuclear forces, the Soviets continued to use the powerful R-7 rocket to showcase its technological prowess to the world. Yuri Gagarin rode an R-7 in his *Vostok* spacecraft on April 12, 1961, and became the first human in space, while frustrated American astronauts prepared for their own flights into space. Kennedy's discomfort over his political position after the Soviet space success was reinforced a week later when American-backed Cuban exiles were turned back in their attempt to invade Communist Cuba at the Bay of Pigs. Conscious of the propaganda value of the string of Soviet space exploits, and worried about the impact of his failure in Cuba, Kennedy responded to Gagarin's flight by setting the goal of landing

American astronauts on the moon before the end of the 1960s.[9] Although the Soviets were slow to respond to Kennedy's lunar challenge, the Soviet space program continued to rack up impressive firsts with the first woman in space in 1963, the first multimember spacecraft crew in 1964, the first walk in space in 1965, and the first photos from the surface of the moon in 1966. By 1966, American astronauts and robot satellites and space probes from the United States began to establish American preeminence in space exploration. After the air force won control of ICBMs and most other long-range missiles in the late 1950s, von Braun and many other members of the army missile team transitioned in 1960 to the civilian space program at NASA to direct the building of the Saturn rockets that powered Apollo spacecraft to the moon. The expertise that the USAF gained in creating ICBMs was also put to work in Apollo.[10] Even before *Apollo 11* astronauts Neil Armstrong and Buzz Aldrin established American primacy in the space race by landing on the moon on July 20, 1969, funding for the space program was being sharply reduced from its high point in 1966. The Republican administration headed by Eisenhower's vice president, Richard Nixon, refocused human space exploration on low earth orbit with the Space Shuttle program, which began in 1972 as Apollo came to an end, but did not begin flying until 1981. The Soviet program to put humans on the moon ultimately failed, but quickly turned in the 1970s to a series of space stations.

During the years of the space race from the 1950s through the 1980s, Atlas earned a prominent place in the history of space exploration. Atlas launch vehicles launched a variety of satellites into orbit around earth, including four US astronauts in 1962 and 1963 in Mercury spacecraft. Atlas rockets, often topped with Agena, Centaur, and other stages, sent robot spacecraft on their way to the moon, Mercury, Venus, Mars, Jupiter, Saturn, and to the edges of the solar system. Atlases launched scientific exploration satellites into earth orbit, along with weather, communications, and national security satellites. By the time the Atlases that derived from the original missile design gave way to a new generation of Atlas rockets based on new bodies and new engines in the new millennium, more than five hundred Atlas rockets, some of them recycled ICBMs, had launched payloads into space. Titan II launch vehicles also carried astronauts into space in the Gemini program, and other Titan rockets and Thor rockets, as well as a derivative design of Thor named Delta, also became workhorses of the US space program from the late 1950s into the twenty-first century.[11] Throughout this time, the R-7 rocket has continued to be widely used, since the end of the Cold War to the present day, in Russian space programs. Advanced

versions of the R-7 are used today to launch humans to the International Space Station.

Space Exploration and Nuclear Weapons

The relationship between the ICBM decisions and the arrival of thermonuclear weapons raises the question of how space exploration would have developed had nuclear weapons evolved in a different fashion. If thermonuclear weapons had been created at a later time, or if military authorities had decided to build ICBMs for another reason, would the first space race of the 1950s and 1960s have stalled, since fewer space launch vehicles were available? While there is limited profit from such hypothetical scenarios, they are useful to make the point that the space race of the twentieth century may not have been as inevitable as it looked at the time. Many have argued about the close-run nature of humanity's reach into space in relation to the Apollo program and events such as the timing of Yuri Gagarin's historic flight into space and even the assassination of President Kennedy. Some have even raised the contingent nature of history with regard to Sputnik and the chain of events surrounding it that caused such shock and consternation in the United States.[12]

The history of space exploration in the twentieth century has traditionally been presented inside the framework of the hopes of many people to journey into outer space, along with the progress of the technologies that made possible the first flights into space. While the roles of the Cold War and of nuclear weapons in facilitating those technologies have always been acknowledged, they have been seen more as the backdrop of the missile and space races of the 1950s and 1960s rather than as driving forces. America's first intercontinental ballistic missile, the Atlas, stands at the fulcrum of both the missile race and the space race. Both it and the R-7 were better suited as launch vehicles and ultimately had a longer life in that role. But without the demand by the military for a long-range ballistic rocket to carry thermonuclear warheads to distant targets, there would have been no Atlas, and the human voyage into space would have taken a different path.

The two rockets built as the first ICBMs for the two superpowers, the Atlas and the R-7, ultimately were more useful as space launch vehicles than as weapons carriers. The R-7 was used to launch satellites even as it underwent testing, while Atlas was held back. This helped foster the illusion that the Soviet Union was ahead of the United States in missile and space technology at the time of Sputnik in 1957. The R-7, owing to Andrei Sakharov's erroneous estimate and

the inflexibility of the Soviet system, could carry a far larger payload than Atlas, and the result was several Soviet space "firsts," culminating in the launch of the first human in space in 1961. The Soviet missile and space programs suffered setbacks, but they were hidden behind a wall of secrecy until the end of the Cold War. At a time when the United States and the Soviet Union were competing for influence in the world, the prestige won by the Soviet Union with its space achievements inspired Kennedy, who was by his own admission not a space travel enthusiast, to challenge the Soviets for this prestige with his lunar goal.[13] The Soviet achievements in space that started with Sputnik also inspired a set of myths about the early missile programs of both superpowers that have persisted to the present. By returning the story of Atlas to its military roots, the history of space exploration moves further from the hopes of its early promoters toward the realities of the military and political factors that came together in the 1950s and 1960s to create the competition in space between the two Cold War superpowers.

Conclusion

This book has sought to liberate the story of the creation of Atlas as America's first ICBM from the prevailing myths that have shrouded it since Sputnik rose into the skies atop the first Soviet ICBM, the R-7. Like the R-7, Atlas was created as a military system with the aim of carrying thermonuclear weapons anywhere on earth in a short period of time. Atlas was created at the precise time it was and not before because of the arrival of thermonuclear weapons that moved ICBMs from the realm of speculation to technical and political feasibility. The US Air Force won the job of building and using long-range offensive missiles, and it was long criticized for not seriously supporting Atlas until 1954. These criticisms have usually missed the serious problems the air force faced in bringing bomber aircraft and their crews, along with the nuclear weapons of the late 1940s and early 1950s, to a state of readiness for their nuclear mission, and the real problems that held back missiles. As fears arose of nuclear war between the United States and the Soviet Union, policymakers from the White House down set defensive missiles as their top priority, and the military services responded to this priority. Advances in nuclear weapons finally dictated the timing of the shift to offensive missiles like Atlas. This study examines, for the first time, Atlas as a part of the nuclear weapons delivery system that it was built to enhance.

Political, economic, and other social factors played important roles in driving decisions on ICBMs, but US military weapons programs during the Cold

War rarely had trouble gaining support from military bureaucracies, politicians, and defense contractors, once their utility as weapons was demonstrated. In the case of ICBMs, the creation of thermonuclear weapons gave promise to decision makers of their effectiveness and feasibility as weapons.[14] Although both the United States and the Soviet Union independently began building their first ICBMs within a few weeks of each other in 1954, in large part because of the creation of thermonuclear weapons, I make no suggestion that this technological change determined the creation of these missiles. In both cases, small teams of missile designers presented a new technology—long-range missiles—to governing authorities who opted to move ahead with that technology for reasons of their own. Soviet authorities were concerned about the limitations of their bomber aircraft, and American leaders, knowing little about what the Soviet military was doing with missiles, feared that the Soviet Union would soon have long-range missiles of its own.

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Historiographical Essay: The Atlas in History

As America's first intercontinental ballistic missile and an important space launch vehicle, Atlas occupies an important place in the history of US missiles and of US space programs. The literature on Atlas until recently has been relatively sparse, and a look at the historiography of Atlas shows how scholars have sometimes misinterpreted events around the creation of missiles.

Despite its importance in the history of space exploration, Atlas took a back seat in histories of space travel to other missiles associated with Wernher von Braun and the team of German rocket experts that worked with him after the war for the US Army and later NASA. Former NASA chief historian Roger D. Launius wrote that what has become known as the "Huntsville School" of history of American space travel and rocketry overstated the contribution of the von Braun team to the development of American rocketry and overlooked the contributions of other individuals and agencies, including the US Air Force.[1]

The most influential historical work about the US government's handling of military missiles, particularly Atlas, pre-1954 has been political scientist Edmund Beard's 1976 book *Developing the ICBM: A Study in Bureaucratic Politics*, which focused on the air force's treatment of these long-range missiles during that time. *Developing the ICBM* was based heavily on air force documents pertaining directly to missiles, and it highlighted differences inside the US Air Force over whether to proceed with building an ICBM.[2] Writing nearly twenty years after Sputnik, Beard emphasized the importance of the Sputnik crisis in the United States and reiterated the belief that the Soviet Union enjoyed an advantage in ICBMs over the United States in the late 1950s. He wrote that although "it became apparent that the early Soviet ICBMs were not readily producible and were not good strategic weapons, it remains true that the Soviet Union had indeed 'beaten' the United States to a vital weapon." To back up this claim, Beard quoted a 1962 article stating that the Soviet R-7 ICBM was superior to the American Atlas ICBM. We know now that while the R-7 was and remains an excellent launch vehicle, it was of little use as an ICBM.[3]

Beard argued that the air force's bureaucratic resistance to ICBMs delayed the development of an American ICBM until 1954, when the change of administrations overcame air force resistance to missiles and led to the creation of an American ICBM. "My opinion is that the United States could have developed an ICBM considerably earlier than it did but that such development was hindered by organizational structures and belief patterns that did not permit it," Beard wrote. He contrasted the air force's preference for aircraft, and particularly bomber aircraft, to its "neglect and indifference" of ICBMs before 1954. Beard gave little attention to the problems that the air force faced with the pace of advances in jet aircraft and nuclear weapons, and to critics of long-range missiles like Vannevar Bush, and passed over the drive to create defensive missiles before ICBMs.[4] He contended that missile development was slowed first because air force leaders saw long-range missiles as "Buck Rogers" weapons of the distant future, and quoted public statements by German rocket experts Wernher von Braun and Walter Dornberger about the possibilities at war's end for their own V-2s to back up his contention that the required missile technology was close at hand in 1945.[5]

Beard called the arrival of thermonuclear weapons a "false issue," asserting as early as 1948 that lightweight nuclear weapons appeared to be feasible because of modest increases in the power of fission weapons. Part of Beard's argument was that the success of thermonuclear bombs was almost assured when Truman decided to proceed with them in January 1950. One of his major sources for this idea was Truman's memoirs—not the most reliable authority on the history of nuclear weapons. In fact, the most crucial theoretical breakthrough for thermonuclear weapons, the Teller-Ulam staged explosion concept, was not postulated until early 1951, long before it was tested. As part of Beard's argument that fission weapons were increasing rapidly in availability and falling in weight after the 1948 Sandstone fission bomb tests, he again quoted Truman as his authority that tactical nuclear weapons were ready for use as early as 1950, which wasn't the case. The biggest weakness in this argument is that it overlooks the vastly greater power of thermonuclear weapons over fission weapons, the factor that led to the loosening of accuracy requirements for ICBMs. Even the creation of lightweight thermonuclear weapons, Beard argued, "did not eliminate Air Staff resistance to ICBMs, but simply caused a retreat to other arguments."[6] Beard has produced persuasive evidence of resistance in the upper reaches of the USAF to Atlas in 1952 and 1953, but his account missed the real technical problems standing in the way of ballistic missiles prior to 1952,

notably those involving guidance and targeting, and the difficulties the air force was facing with bomber aircraft.

Cultural Resistance

Even with its deficiencies, *Developing the ICBM* remains a groundbreaking work in the history of missiles because it was arguably the first book in that subject area to try to put these weapons into their social context instead of the all-too-common concentration on the individual artifact. The influence of this book derived in part from this fact. While this study questions the social aspect of the air force's decision-making on Atlas as presented by Beard and others, it in no way denies that social forces caused the USAF to proceed with the Atlas ICBM in 1954. Previous works on the Atlas decision did not factor the wider policy context affecting nuclear weapons in the late 1940s or the air force's challenges making their bomber force effective as a means of delivering nuclear weapons.

Both Beard and air force historian Robert L. Perry were heavily influenced by the account of Elting E. Morison, the eminent Massachusetts Institute of Technology historian of the culture of technology, in his classic 1950 essay "Gunfire at Sea: A Case Study of Innovation." Morison outlined the troubles surrounding the US Navy's adoption of continuous-aim gunnery from its ships from 1900 to 1902 after the process had been created in the Royal Navy in 1898. Prior to the invention of continuous-aim gunnery, guns could be fired from ships only at certain times while a ship was rolling. In 1900, a junior officer in the US Navy, William S. Sims, introduced the idea of continuous-aim gunnery to his colleagues. Despite the great improvement this new method of gunnery represented for naval gunnery, the idea met strong resistance inside the US Navy that was only overcome with the personal intervention of President Theodore Roosevelt. Some resisted this change in practice because it portended and ultimately led to numerous social and procedural changes aboard ships, Morison explained. The sailors and officers identified themselves with the existing guns and procedures. "The opposition, where it occurs, of the soldier and the sailor to such change springs from the normal human instinct to protect oneself, and more especially, one's way of life," Morison wrote. Perry, in his turn, compared air force officers' "deep and sincere opposition to the accelerated development of ballistic missiles" between 1950 and 1955 to the 1890s US Navy as described by Morison.[7] The air force officers' stand, Perry explained, represented "cultural resistance to the innovation represented by ballistic missiles." Beard highlighted Perry's statements about the air force's cultural

resistance to change, and Morison's ideas about the need for outsiders to make change in military practice. Beard concluded that the USAF's treatment of both the bomber and the ICBM show that a "revolutionary new weapon may be subordinated to outdated doctrine or outdated methods" in the wrong hands.[8]

The air force's attitude to missiles before 1954 is not directly comparable to the navy's resistance to the new method of gunnery from 1900 to 1902. The new gunnery method involved some minor changes to the guns, training, and practice for the gunners. It had already been invented and was ready for almost immediate implementation on ships. Despite the ease of implementation, the new process ultimately led to a major enhancement in the status of gunners and what Morison called the "dislocation" of naval society. ICBMs overtaking bombers would undoubtedly lead to a great dislocation in air force society. But even in 1954, the deployment of the first American ICBM was still five years in the future, and the maturation of ICBMs as a weapons system was another five years beyond that. Before 1954, the ICBM was far from being a proven weapon or even a viable concept. Although air force leaders believed in the early 1950s that a change from bombers to ICBMs would disrupt the society of the air force, whether this was a major factor in decision-making was questionable because the ICBM was still years away from being proven or being put into use. Since Atlas ICBMs began being deployed in 1959, the USAF maintained its force of bomber aircraft alongside its ICBM force. This also throws into question the idea that ICBMs would disrupt social relations inside the air force by replacing bombers with missiles.[9]

Gen. Curtis LeMay, the longtime head of the Strategic Air Command and later USAF chief of staff, remained opposed to ICBMs until the Minuteman ICBM program began in 1958. While LeMay's opposition between 1954 and 1958 might more aptly fit the comparison that Beard and Perry made between the air force's resistance to ICBMs before 1954 and the US Navy's opposition to new firing methods at the beginning of the twentieth century, the fact that LeMay's opposition disappeared in the face of an ICBM system that was far superior to Atlas and Titan suggests that LeMay's attitude to ICBMs represented something other than simple cultural resistance.[10]

Robert L. Perry

Edmund Beard was heavily influenced by the work of historian Robert L. Perry, who first wrote on this topic in 1963, at the height of the space race, while working for the USAF. Perry's article noted that while the commander of the Army

Air Forces, Hap Arnold, saw a need for ICBMs, "leading civilian scientists" and others were not as prescient and believed the Soviet Union "was incapable of developing an advanced technology."[11] Even when the USAF reinstituted its ICBM program in 1950, Perry contended that bomber aircraft and air-breathing missiles retained their higher priority, and the ICBM program "remained a pedestrian effort" for four years. Perry claimed that in 1953, US intelligence "acquired reliable information that the Soviet Union was well along in the development of a long-range rocket weapon," although no evidence has emerged to back up this claim.[12] He also noted the breakthrough in thermonuclear weapons, saying, "a generation of scientists and military planners more concerned about the danger of losing a new war than with preserving the tactics of the past war edged into the policy councils of the defense establishment." These developments led to the 1954 Tea Pot Committee report and the top priority effort given to the Atlas ICBM.[13]

Perry wrote again about ballistic missile decisions in a 1967 paper for RAND, where he compared air force behavior with Morison's description of the US Navy at the turn of the century. Perry argued that the contending factions of the air force, including strategists and scientists, fought over whether to advance missiles at the possible expense of aircraft programs. Experts such as Vannevar Bush had used technological and financial shortfalls to justify the 1947 program cutbacks, but Perry argued that "institutional influences and shortsighted technical planning appear, in retrospect, to have been at least as important." Perry contended that missiles won new interest in the air force because many outside experts used by the USAF began to question whether bombers would be able to penetrate defenses using missiles and more sophisticated electronics. As well, he argued that progress was being made in technologies necessary for long-range missiles.[14]

Thomas Hughes's Analysis

One of the foremost historians of technology, Thomas P. Hughes, examined the Atlas program in depth in his 1998 book *Rescuing Prometheus*. There he argued that "a conservative momentum, or inertia" slowed the program before 1953, involving "both institutions and hardware."[15] But in 1952 and 1953, a "confluence of scientific and technological events substantially altered Air Force policy" when it learned that lightweight thermonuclear warheads were possible, and a decline in Soviet bomber production suggested that the Russians were turning to missiles.[16] Summarizing Morison's arguments in the case of naval

gunnery, Hughes explained that Donald Quarles and Trevor Gardner provided the necessary force to overcome the inertia among both air force officers and skeptics of missiles in the scientific community such as Vannevar Bush, much as Theodore Roosevelt had done a half century earlier with the navy's resistance to new gunnery practices. Hughes added that "physical objects with specific characteristics generate a resistant mass weighted in favor of the status quo."[17] Hughes did not elaborate further in *Rescuing Prometheus*, but he wrote elsewhere that large technological systems become large vested interests of their own as the people who run them develop specialized skills and knowledge, especially for individual systems. A change in or loss of the system would result in these people becoming deskilled and the loss of hardware capital. The skilled operators and financial backers of these systems "construct a bulwark of organizational structures, ideological commitments, and political power to protect themselves and their system," Hughes explained, generating conservative momentum where mature systems can block newer systems that challenge them. In the case of the air force, the conservative momentum of bomber aircraft and their skilled personnel was seen as standing in the way of ICBMs.[18]

In *Rescuing Prometheus*, Hughes quoted Perry as saying that air force officers resisted ICBMs because of their "affection" for bombers, and Beard as arguing, "the Air Force bureaucracy instinctively resisted radical innovation as disrupting established procedures and diluting the power of the bureaucracy."[19] Although there is some truth to these assertions, they suggest that the air force was a comfortable and almost static institution during the first decade after World War II. In fact, that decade saw many major changes in the air force that severely challenged hierarchies, established procedures, and the "status quo" mentioned by Hughes. In the early months after the war, the air force went through a rapid demobilization and then in the next few years had to rebuild its personnel base. The air force had to make the change from propeller to jet aircraft, itself a major shift. And the arrival of nuclear weapons in 1945 also marked a radical departure in doctrine and operating procedures. The air force fought for and gained its long-sought independence from the US Army in 1947. Even without missiles in the mix, the first decade after World War II was one of startling change for the US Air Force.[20]

Other Historical Treatments

Hughes and Beard were among the historians who, sensitive to the role of political forces in driving technology, argued that the arrival of the Eisenhower

administration prompted the air force to proceed with ICBMs. This group also included Walter A. McDougall in his classic history of early space programs, Rip Bulkeley, who wrote a book on early US space policy, and former RAND analyst Carl H. Builder in his study of air power theory and the USAF.[21] In his discussion of early postwar missile work in the United States, McDougall used many arguments from Beard's book, but he firmly placed missile development inside the context of wider developments in the Cold War and in the struggle between the services during Truman's postwar military reorganization. The deepening confrontations of the Cold War in the late 1940s, culminating in the Korean War, ended Truman's attempts to restrain military spending, including spending on missile programs. McDougall concluded that the creation of lightweight thermonuclear weapons broke down air force resistance to ICBMs, this decision being formalized early in 1954 following reports from RAND and the Tea Pot Committee. This brought McDougall's account to a central point of his thesis: that the space race and the Cold War arms race created competing technocracies in the United States and the Soviet Union.[22]

The strong evidence tying the air force's decision to move on ICBMs to the arrival of lightweight thermonuclear weapons in the early 1950s was cited by the first historians to write about the issue, the three authors of the official 1966 NASA history of Project Mercury, which used Atlas to loft the first American astronauts into earth orbit.[23] Their book *This New Ocean: A History of Project Mercury* dealt briefly with the history of Mercury's primary launch vehicle, Atlas, emphasizing the importance of lightweight thermonuclear weapons in facilitating the missile's development. This account also covered the development of technologies necessary for human spaceflight, including H. Julian Allen's work on blunt reentry bodies.[24]

Historians who have mainly written on military topics—Jacob Neufeld, John Clayton Lonnquest, Robert Frank Futrell, and Stephen B. Johnson—credited the thermonuclear breakthrough as the crucial factor that led the USAF and the Eisenhower administration to proceed with Atlas and other ICBMs. Much of the historical writing on this topic has come in the form of studies sponsored by the US Air Force, including much of Perry's work, Jacob Neufeld's *Ballistic Missiles in the United States Air Force 1945–1960*, and other more narrowly focused air force studies.[25]

Jacob Neufeld, in his 1990 official history of the air force's missile programs between 1945 and 1960, concentrated on the air force's institutional rivalry with the army and navy for control of missile programs, but gave little attention

to the wider political situation or the other issues facing air force leaders at the time. He did not highlight outside advice the air force received, either from bodies like the Research and Development Board or the RAND Corporation. Neufeld wrote that interservice rivalry over ballistic missiles "postponed final decisions and unnecessarily delayed the programs." The air force ballistic missile program "foundered" because it lacked "an institutional advocacy group when it competed for funds." In Neufeld's account, the jostling for position between the services went on until the reorganization of military research and development under Eisenhower.[26] Robert Frank Futrell's exhaustive official 1989 history, *Ideas, Concepts, Doctrine: Basic Thinking in the United States Air Force, 1907–1960*, suggested that the new thermonuclear weapons, along with other technical innovations, made the Atlas ICBM technically feasible in 1953, leading Trevor Gardner to persuade the USAF to speed development of the new ICBM.[27]

In his 1996 dissertation on Gen. Bernard Schriever's role in Atlas, John Clayton Lonnquest argued that the air force did not strongly support missiles, and that Trevor Gardner and Schriever "waged a carefully orchestrated campaign, much of it conducted outside of the Air Force," to accelerate Atlas. Lonnquest argued that, before 1953, the air force favored winged missiles over ballistic missiles for several reasons, including winged missiles' resemblance to aircraft. One reason for this bias was that wingless ICBMs might strengthen Army Ordnance's case to run the missile program because ballistic missiles resembled artillery shells more than winged aircraft. In the late 1940s, the USAF's "small cadre of missile advocates had neither the organizational support nor the technological viability" to press for the ICBM, Lonnquest wrote, a situation that had changed by 1951.[28]

Other Works

Rip Bulkeley's 1991 study of the Sputnik crisis in the United States included the most thorough examination to date of the attitudes of those in the upper reaches of the Truman administration toward rockets and space. But like so many other writers, Bulkeley looked backward from the launch of Sputnik and the crisis that followed it, rather than examining the actions of Truman administration officials in the context of the time. Bulkeley minimized the impact of air force preference for aircraft over missiles, writing that the air force faced severe budget pressures at the time. Unlike most other writers, Bulkeley explained that ICBMs, along with other nuclear weapons delivery systems, were

hobbled owing to inadequate target maps and other information about potential targets, both inside and outside the Soviet Union.[29]

A technical issue that has often been raised is the poor accuracy that sharply limited the effectiveness of German V-2 missiles and early postwar American missiles. But Donald MacKenzie's landmark 1990 study *Inventing Accuracy* questioned widely held assumptions about the importance of accurate guidance to the early development of ICBMs. In a section based largely on Beard's *Developing the ICBM* and other secondary sources, MacKenzie wrote that before the time of the Tea Pot Committee, accuracy requirements were set too strictly for ICBMs. But even so, ICBMs were going to require a "quantum leap in accuracy from the V-2." The air force's preference for bomber aircraft over missiles during this time may have driven accuracy requirements for missiles, he suggested.[30]

Historian Stephen B. Johnson wrote an important history in 2002 of systems management in missile and space programs, *The Secret of Apollo*. Here he discussed Atlas at some length, particularly the work of Schriever and Ramo-Wooldridge in bringing systems management to bear in developing Atlas, Titan, and Thor. His account of the beginnings of Atlas highlighted the impact of the new thermonuclear weapons on Schriever, Gardner, and von Neumann, who in turn accelerated Atlas. Johnson did correctly point out that the arrival of ICBMs meant disruptions to the organization and culture of the US Air Force, although he related it to the push-button nature of missiles and the fact that each missile could be used only once, which had major implications for testing and production. He did not tie these changes to air force resistance to ICBMs.[31]

In the realm of popular books, Atlas and the people who built it have received scant attention, especially when compared to the wealth of books on von Braun and his team. In 1960, John L. Chapman wrote a popular history of the Atlas missile that focused on the work of the Convair team under Charlie Bossart that started with the MX-774 missile. Chapman blamed the demise of the MX-774 on the influence of the many "diehard fliers" in the air force. Even in 1951 and 1952, top officials in the Pentagon considered the Atlas program to be still in the realm of Buck Rogers. In Chapman's account, the successful test of the first thermonuclear bomb in November 1952 led people like Gen. Bernard Schriever and Trevor Gardner to see the potential of Atlas in 1953.[32] Nearly fifty years would elapse until the appearance of the first popular biography of Gen. Bernard Schriever. In his 2009 book *A Fiery Peace in a Cold War*, journalist and author Neil Sheehan discussed how Schriever and Gardner

worked to accelerate the Atlas program when John von Neumann and Edward Teller concluded in 1952 that lightweight thermonuclear bombs would soon be available.[33] While Sheehan also mentioned interservice rivalries and Gen. LeMay's antipathy to ICBMs, both were brought up in relation to events that took place after the Tea Pot Committee report.[34]

Social Forces in the ICBM Decision

This book places the decisions to proceed with ICBMs into the wider context faced by decision makers in the first decade following World War II. The employment of the V-2 ballistic missile during that war showed that rockets of this type had promise as weapons because there was no way to defend against them once they were launched. The possibilities of their use as delivery vehicles for nuclear weapons were raised within hours of the first use of nuclear weapons against Japan in August 1945. But the V-2 showed that ballistic missiles also had major limitations, especially when it came to accurately guiding weapons to distant targets. Further study showed other technical issues for ballistic missiles, including the problem of protecting warheads from reentry heating during the final stages of their flight to targets. These problems were laid out in reports by Hugh Dryden and others in the *Toward New Horizons* report in 1945. Vannevar Bush made public his doubts about missiles that year in congressional testimony and elsewhere. In short, ICBMs didn't seem in the late 1940s to be the obvious solution to the problem of sending nuclear weapons to distant targets, unlike the 1970s, when the technical problems were distant memories and ICBMs were the primary delivery vehicle for nuclear weapons. In the late 1940s, most responsible officials inside and outside the air force were far more interested in building missiles to defend against Soviet bombers and missiles.

Moreover, the late 1940s was a time of great policy flux, as the Soviet Union moved from being an ally in the war against Nazi Germany in 1945 to Cold War adversary by 1948. Until then, the official US government policy on nuclear weapons called for international control, and even after that ended as the Cold War deepened, America's nuclear weapons weren't released to military control from the Atomic Energy Commission until 1951. America's first nuclear weapons were heavy, large, and required final assembly just before use. They were also in extremely short supply before 1948. The air force, for its part, saw its ranks sharply reduced in the months after the end of World War II, and then it had to rebuild itself as a force capable of delivering nuclear weapons to the Soviet

Union. This required development of new aircraft that didn't come on stream until the end of the decade. And the rebuilt Strategic Air Command needed to train its aircrews, establish bases in friendly countries, and develop new procedures like in-flight refueling to extend its reach. All this occupied the air force's attention. And between the end of World War II and the beginning of the Korean War in 1950, the US military had to operate with austere budgets that have not been seen since.

The Korean War loosened purse strings for the military, and the appointment of retiring Chrysler chief K. T. Keller as the Defense Department's missile czar that fall meant a new priority for missile research and development—but the priority remained on defensive missiles. Reflecting fears caused in 1949 by the first Soviet nuclear explosion, 1950 saw development work begin on US thermonuclear weapons, which would be hundreds of times more powerful than existing fission bombs. In 1950 and 1951, studies into long-range missiles by the RAND Corporation began to more strongly support ballistic missiles over winged cruise missiles for long-range offensive purposes. The formal air force program that led to Atlas began in 1951, and the following year saw the first thermonuclear explosion, research showing the possibility of lightweight thermonuclear weapons, and advances in protecting warheads reentering earth's atmosphere at high speeds. In 1953, officials in the new Eisenhower administration, scientists, and air force officers began to push for a stronger ICBM development program, which began after the report of the Tea Pot Committee in 1954.

Sputnik's Shadow

The political crisis that followed Sputnik has strongly colored how historians and other scholars, including Beard and others discussed in this essay, looked at the competition in space between the Soviet Union and the United States that culminated in the Apollo moon landings. Views about the Sputnik crisis and the space race that followed have also been reflected in historical accounts of that period. But the passage of time since Sputnik has led to new interpretations of this event and its importance.

Early historical accounts of the space race were written in most cases by people who strongly supported space exploration, and few were more successful in promoting space travel than Wernher von Braun, who wrote highly popular books about space exploration. Works by von Braun and associates such as Willy

Ley promoted the idea of three pioneers—the Russian Konstantin E. Tsiolkovsky, the American Robert H. Goddard, and the Transylvanian-born German, Hermann Oberth—who inspired people like von Braun and Korolev to build the rockets and spacecraft of the 1960s space race.[35] Even at a time when space budgets were being cut as the Apollo astronauts flew to the moon and the first probes to fly by Mars showed little promise of life on the red planet, von Braun looked to expeditions to Mars, perhaps as early as the 1980s. Holding out the idea of a new era of discovery, he ended one book by asking whether humanity's "insatiable curiosity and boundless energy" would lead to the exploration of new worlds.[36]

Alex Roland's assessment of Sputnik as part of a campaign for larger military forces raises the question of whether the Sputnik-influenced historiography of the Cold War period helped fuel the arms race.[37] By looking at the development of space travel and of rockets as part of humankind's move into the cosmos rather than as an episode in the Cold War, spaceflight history did not face up to the implications of that reality. The early history of space exploration should be reexamined in light of the fact that it was sparked to a large degree by the imperatives of nuclear weapons. The creation of thermonuclear weapons involved conflict between scientists, politicians, and others over the morality of creating such powerful weapons, and the human agency involved in the creation of thermonuclear weapons also extended to the missiles and space launch vehicles that were originally created to deliver them in case of war.

But humankind's curiosity and energy were turning to problems on earth, thanks in part to social movements unleashed in the 1960s. While space programs continued in the 1970s and 1980s, they focused increasingly on helping to deal with problems on earth using remote sensing satellites, shuttle craft, and space stations in low earth orbit. During those years, historians and other scholars began to look more critically at space exploration. Sociologist William S. Bainbridge suggested that space programs resulted from small numbers of motivated individuals such as von Braun persuading government leaders to support these programs, and questioned whether space programs enjoyed support from the public or scientists.[38] In 1985, Walter A. McDougall's landmark history of the space race was published. McDougall, a historian of diplomacy, took a more critical look than previous writers at the underpinnings of the space race. But he followed them in viewing the Sputnik-sparked space race as a major turning point in human history, despite mounting evidence that this was not the case. He argued that, as a result of the Cold War and Sputnik, the

United States and the Soviet Union turned themselves into a new kind of state, the technocracy.[39]

The late 1980s saw startling changes in the Soviet Union and Eastern Europe that culminated in the dissolution of the Soviet Union and the end of the Cold War in 1991. These events helped accelerate the reassessment of the 1950s and 1960s space race, not least because they made possible the opening of Soviet-era archives and declassification of US government documents that shed new light on what decisions were made about missiles and spacecraft, and how and why they were made. The new interpretations of this history became part of what Launius called the New Aerospace History, which aimed to move beyond concentration on individual aircraft or spacecraft to wider social, political, and cultural issues relating to aviation, missiles, and space vehicles.[40] Historians such as Howard McCurdy questioned the air of inevitability that surrounded the early flights into space, when promoters of space travel invoked the image of the frontier in the American west to justify Apollo. Frontier imagery has long been debunked by scholars and more recently attacked by aboriginal peoples and others who were victimized by colonizers. McCurdy, by detailing how Cold War concerns were used to sell space travel to Americans, has joined the ranks of historians who have reassessed the place of Sputnik.[41] In 1997, McDougall wrote that he was moving away from his 1985 judgment that Sputnik was a "saltation, an evolutionary leap." He explained: "In retrospect . . . the post-Sputnik burst of enthusiasm for state-directed technological revolution seems to have been an ephemeral episode in the larger history of the Cold War, rather than the Cold War having been an episode in the larger story of the march of technocracy."[42]

As part of these new views of the Cold War and of Sputnik, this book has attempted to free the history of the creation of America's first ICBMs from the myths that arose during the political storm in the United States that followed the launch of Sputnik. The creation of ICBMs and most early space launch vehicles were more closely linked to the development of thermonuclear weapons, which themselves were created as part of the Cold War, than commentaries and histories produced in the shadow of Sputnik have acknowledged.

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Notes

INTRODUCTION

1. Michael J. Neufeld, "Orbiter, Overflight, and the First Satellite: New Light on the Vanguard Decision," in Launius et al., *Reconsidering Sputnik*, 237–8.

2. Beschloss, *Crisis Years*, 328–31.

3. Neufeld has cut through the myths surrounding von Braun in many works, such as *Von Braun* and "Orbiter, Overflight, and the First Satellite." McCurdy, *Space and the American Imagination*, cast a critical eye on von Braun's work popularizing space exploration in America, as did Launius in his discussion of newer currents in the history of spaceflight, "Historical Dimension of Space Exploration."

4. See Hughes, *Rescuing Prometheus*; Johnson, *Secret of Apollo*; and Sheehan, *Fiery Peace in a Cold War.*

5. Beard, *Developing the ICBM*, 4, 8, 218.

6. Launius, "Historical Dimension of Space Exploration."

CHAPTER 1: Weapons of the Future

1. Ordway and Sharpe, *Rocket Team*, 180–220; Werrell, *Evolution of the Cruise Missile*, 41–62.

2. Ordway and Sharpe, *Rocket Team*, 195. For more on the creation of the V-2, see Neufeld, *The Rocket and the Reich*.

3. Eisenhower, *Crusade in Europe*, 58–60; Ordway and Sharpe, *Rocket Team,* 221–38.

4. This history is covered in many texts, including Ley, *Rockets*; von Braun and Ordway, *History of Rocketry and Space Travel*; Baker, *The Rocket*; Burrows, *This New Ocean*; Heppenheimer, *Countdown*; and Gainor, *To a Distant Day*.

5. Many types of engines—including rocket engines, jet engines, and internal combustion engines—require an oxidizer to burn fuel. Oxygen is the most common but not the only oxidizer. Many engines on earth get their oxygen from the air, but rockets that operate outside the atmosphere must carry their own oxidizers.

6. The lives of Bing, Esnault-Pelterie, Oberth, Tsander, and Tsiolkovsky are also extensively covered in the general histories cited in note 4 above. Unfortunately, there is no thorough English-language biography of Tsiolkovsky that reflects the new findings on his life that have come to light since the fall of the Soviet Union. Siddiqi's *Red Rockets' Glare* contains a great deal of up-to-date information on Tsiolkovsky.

7. There are several books on Goddard, including Clary, *Rocket Man*, and Lehman, *This High Man*. Clary's book has debunked many popular myths about Goddard's relationships with journalists. Another up-to-date interpretation can be found in Frank H. Winter, "The Silent Revolution: How R. H. Goddard Helped Start the Space Age" (paper IAA.6.15.1, presented at the 55th Congress of the International Astronautical Federation, Vancouver, BC, October 4–8, 2004).

8. See Emme, *History of Rocket Technology*, 19–27, 46–66.

9. Baxter, *Scientists against Time*, 201–11.

10. The history of early Soviet rocket efforts is outlined in Siddiqi, *Red Rockets' Glare*; idem, *Challenge to Apollo*; and Zaloga, *Target America*, 64–7, 111–2. For more on Korolev, see Harford, *Korolev*.

11. Siddqi, *Red Rockets' Glare,* 186–240; idem, *Challenge to Apollo*, 18–22. The Americans repaid the Soviet compliment in the summer of 1945 when they surrendered the main V-2 production plant at Nordhausen to Russian forces as called for in Allied agreements, but only after removing V-2 rockets, plans, and parts.

12. The story of von Braun and German rocket work is told in Neufeld, *Von Braun*. See Bush, *Modern Arms and Free Men*, 83–4, and Neufeld, *Ballistic Missiles in the United States Air Force*, 2.

13. Neufeld, *The Rocket and the Reich*, 272–4. In today's dollars, the Manhattan Project cost nearly $27 billion and the V-2 about $6 billion.

14. For an excellent summary of technical problems facing rocket builders, see Johnson, *United States Air Force and the Culture of Innovation*, 4–7. A work that discusses the dangers of Titan missiles and their hypergolic fuels is Schlosser, *Command and Control*.

15. Hanle, "Near Miss," 78–80; Rosenberg, *Air Force and the National Guided Missile Program*, 11–3. The person in authority who assigned missiles to McClelland is unknown. The Air Staff continued in a similar form after 1947 to serve the secretary and chief of staff of the US Air Force. For more information on the structure of the Air Staff, see MacCloskey, *United States Air Force*, 85–94.

16. Frank J. Malina, "Origins and First Decade of the Jet Propulsion Laboratory," in Emme, *History of Rocket Technology*, 60–2; Koppes, *JPL and the American Space Program*, 18–22; Julius H. Braun, "The Legacy of HERMES" (presented at the 41st Congress of the International Astronautical Federation, Dresden, Germany, October 6–12, 1990); "Hermes Guided Missile Research and Development Project," prepared for Technical Liaison Branch, Office of the Chief of Ordnance, Department of the Army, September 25, 1959, in NASA Headquarters History Office Historical Reference Collection; Lt. Col. John F. O'Neill, Memorandum for Record, "Air Force Administration of Army Ordnance Guided Missile R & D Projects," July 18, 1949, in RG 341, Guided Missiles Branch, Box 115, NA.

17. Hanle, "Near Miss," 305–42; Werrell, *Evolution of the Cruise Missile*, 62–8.

18. Statement of Rear Adm. John T. Hayward, Assistant Chief of Naval Operations for Research and Development, "History of the Navy Entry into the Guided-Missile Program," March 3, 1959, House of Representatives, Subcommittee of the Committee on Government Operations, *Organization and Management of Missile Programs*, 431–4.

19. McCullough, *Truman*, 400–401, 447, 454–7; Harry S. Truman Presidential Library, "Press Release by the White House, August 6, 1945, Subject File, Ayers Papers," accessed July 24, 2012, http://www.trumanlibrary.org/whistlestop/study_collections/bomb/large/documents/pdfs/59.pdf#zoom=100. For more on the development of the first fission bombs, see Rhodes, *Dark Sun*.

20. Truman Library, "Press Release by the White House, August 6, 1945."

21. See Ward Wilson, "The Bomb Didn't Beat Japan . . . Stalin Did: Have 70 Years of Nuclear Policy Been Based on a Lie?," *Foreign Policy*, May 29, 2013, http://www.foreignpolicy.com/articles/2013/05/29/the_bomb_didnt_beat_japan_nuclear_world_war_ii. Historian Barton J. Bernstein has argued that while the bomb was primarily used to induce Japan's surrender, the idea that it would impress the Soviets was a "confirming" purpose. "Atomic Bombings Reconsidered," *Foreign Affairs* (January/February 1995) 135–52. The case that Truman used the bomb to send a message to the Soviets was put most controversially by Alperovitz in *Atomic Diplomacy*.

Truman's policies have also been criticized by historians who take a revisionist view of the Cold War, notably Walter LaFeber and Gabriel Kolko. The work of these historians is critically analyzed by Ferrell, *Harry S. Truman and the Cold War Revisionists*. Truman's handling of nuclear weapons is also discussed in, among others, Williamson and Rearden, *Origins of U.S. Nuclear Strategy*; Rosenberg, "Origins of Overkill"; and Alperovitz, *Decision to Use the Atomic Bomb*.

22. Hanson W. Baldwin, "The New Face of War: Veiled by Atomic Bomb's Potentialities, Strife with Japan Poses New Planning," *New York Times*, August 8, 1945, 4.

23. Guided Missiles Committee, OSRD, "Guided Missiles for Use against Japan," August 10, 1945, with attached letter from Bradley Dewey to Vannevar Bush, in RG 156, Office of the Chief of Ordnance, Records Relating to the Army Guided Missiles Program, Box 79, NA.

24. Lehman, *This High Man*, 382–99.

CHAPTER 2: The Bomb and the Military in the Postwar World

1. The US Army Corps of Engineers was organized into districts; the Manhattan District oversaw the atomic bomb project, with a name designed to conceal its real purpose. Although the project office was in Manhattan, the district had no geographic boundaries.

2. See the discussion of this controversy in chap. 1, note 21.

3. The best-known biography of the former president is David McCullough's sympathetic treatment in *Truman*. An excellent source is Robert J. Donovan's two-volume history of Truman's presidency, *Conflict and Crisis*, as well as his *Tumultuous Years*. Other studies of his presidency include Ferrell, *Harry S. Truman and the Cold War Revisionists*; Hamby, *Man of the People*; Leffler, *Preponderance of Power*; and Hogan, *Cross of Iron*. Truman wrote his two-volume memoir *Memoirs*.

4. See Harrington, *Berlin on the Brink*, 83.

5. Parrish, *Behind the Sheltering Bomb*, 155–62; Bundy, *Danger and Survival*, 130–96. Herken's *Winning Weapon* contains a critical and perceptive discussion of the Acheson-Lilienthal Report and the Baruch plan (151–91). US Department of State, "The Acheson-Lilienthal & Baruch Plans, 1946," accessed June 24, 2009, http://www.state.gov/r/pa/ho/time/cwr/88100.htm; Bernard Baruch, Address to the United Nations Atomic Energy Commission, June 14, 1946, President's Secretary's Files, File "Baruch," Harry S. Truman Presidential Library and Museum (HSTL). See also Gaddis, *Cold War*, 54–56.

6. Leffler, *For the Soul of Mankind*, 41–75; Craig and Radchenko, *Atomic Bomb*, 111–34; Rosenberg, "Origins of Overkill," 11–13. Debate continues on whether the United States, the Soviet Union, or both were to blame for escalating tensions leading to the Cold War in the late 1940s. Leffler, *For the Soul of Mankind* suggested that, in 1946, both Truman and Stalin "wavered between toughness and firmness" (48). Gaddis, *Cold War* noted that it is difficult to say exactly when the Cold War began, but the growing insecurity on all sides was "generated by the efforts the wartime allies were making to ensure their own postwar security" (27).

7. Parrish, *Behind the Sheltering Bomb,* 161–2.

8. Rosenberg, "Origins of Overkill," 3–71; Office of the Assistant to the Secretary of Defense (Atomic Energy), *History of the Custody and Deployment of Nuclear Weapons*, 1–22; Leffler, *Preponderance of Power*, 406; Harry S. Truman to James Forrestal, August 6, 1948, Confidential Files, Atomic Bomb and Energy 1948–49 Folder; Gordon Dean, Chairman, Atomic Energy Commission, to James S. Lay, National Security Council, June 24, 1952, President's Secretary's File, NSC-Atomic File, HSTL; Office of the Assistant to the Secretary of Defense (Atomic Energy), *History of the Custody and Deployment of Nuclear Weapons*, 1–35. The military was allowed to take control of nonnuclear components of nuclear bombs in 1950, and Truman approved military custody of full components of a small number of nuclear bombs under tight

restrictions in 1951. The restrictions were loosened in 1952 and again after Eisenhower took office in 1953. There is a large literature on the history of nuclear weapons during this time, including Rhodes, *Dark Sun*.

9. Rosenberg, "U.S. Nuclear Stockpile," 25–30.

10. Rosenberg, "U.S. Nuclear Stockpile," 25–30.

11. Rosenberg, "Origins of Overkill," 11.

12. Hewlett and Duncan, *Atomic Shield*, 43.

13. Borowski, *Hollow Threat*, 103, 105; Hewlett and Duncan, *Atomic Shield*, 47–8, 141–9; Williamson and Rearden, *Origins of U.S. Nuclear Strategy,* 189; Hansen, *US Nuclear Weapons*, 31–4, 122–4.

14. Freedman, *Evolution of Nuclear Strategy*, 48–51.

15. Rosenberg, "Origins of Overkill," 14; Herken, *Winning Weapon*, 196–9; Leffler, *Preponderance of Power,* 406; Office of the Assistant to the Secretary of Defense (Atomic Energy), *History of the Custody and Deployment of Nuclear Weapons*, 1–35.

16. Rhodes, *Dark Sun*, 282; Gaddis, *We Now Know*, 111–2. Emphasis original.

17. Smith, *Air Force Plans for Peace*, 51.

18. Smith, *Air Force Plans for Peace*, 50–3, 81–2; Herken, *Winning Weapon,* 199–200, 219. See also Sherry, *Preparing for the Next War,* 159–90, 213–9.

19. Borowski, *Hollow Threat*, 94–5.

20. US Strategic Bombing Survey, *Over-all Report*, 15–6; MacIsaac, *Strategic Bombing in World War Two,* 145–6. Herken's *Winning Weapon* contains a more critical view of the effects of air force bombing (209–13).

21. Borowski, *Hollow Threat*, 20–3.

22. Werrell, *Death from the Heavens*, 125–8, 152–4. See also Freedman, *Evolution of Nuclear Strategy,* 22; Sherry, *Rise of American Air Power*, 353–60; Gentile, *How Effective Is Strategic Bombing?*

23. Biddle, *Rhetoric and Reality in Air Warfare*, 9.

24. Smith, *Air Force Plans for Peace*, 17; see also Freedman, *Evolution of Nuclear Strategy*, 22–4.

25. Parrish, *Behind the Sheltering Bomb,* 111; Mets, *Master of Airpower,* 312; Testimony of Gen. Carl Spaatz, March 6, 1947, in House of Representatives, Subcommittee of the Committee on Appropriations, *Military Establishment Appropriation Bill for 1948*, 604.

26. Kolodziej, *Uncommon Defense and Congress*, 38–58.

27. Borowski, *Hollow Threat*, 150–1, 198–200; Smith, *Air Force Plans for Peace*, 84–96. See also Willliamson and Rearden, *Origins of U.S. Nuclear Strategy*, 60, 78, 191; and Warner R. Schilling, "The Politics of National Defense: Fiscal 1950," in Schilling et al., *Strategy, Politics and Defense Budgets*. Wolk, *Struggle for Air Force Independence*, 49–85, has a long discussion on the air force's call for enlargement to seventy groups in the late 1940s. One major issue was that the USAAF believed it needed to be ready almost immediately to fight a new war.

28. Borowski, *Hollow Threat*, 27–90.

29. Borowski, *Hollow Threat*, 94–105.

30. Donovan, *Tumultuous Years*, 53; Bradley and Blair, *General's Life*, 488. Williamson and Rearden, *Origins of U.S. Nuclear Policy*, 55, use similar language to describe this dispute, and added that the wounds took decades to heal.

31. Barlow, *Revolt of the Admirals*, 23–32. Barlow tells the unification story from the navy viewpoint, and the US Air Force viewpoint is set out in Wolk, *Struggle for Air Force Independence*. Omar Bradley's views of unification are set out in *General's Life*, 487–513. Independent perspectives of this dispute are provided by Caraley, *Politics of Military Unification*; Boettcher, *First Call*, 55–135; and Donovan, *Tumultuous Years*, 53–65.

32. Harry S. Truman Presidential Library and Museum, "Public Papers of the Presidents: Harry S. Truman: Special Message to the Congress Recommending the Establishment of a Department of National Defense," December, 19 1945, http://www.trumanlibrary.org/publicpapers/index.php?pid=508&st=&st1=; Millis and Duffield, *Forrestal Diaries*, 146–7.

33. Millis and Duffield, *Forrestal Diaries*, 146–9.

34. Barlow, *Revolt of the Admirals*, 24, 32–44, 105–30; Caraley, *Politics of Military Unification*, 96–8; Wolk, *Struggle for Air Force Independence,* 38–40, 161–3; Boettcher, *First Call*, 82–8. For background on the RAF, see Ransom, "Politics of Air Power," and Hyde, *British Air Policy between the Wars*. The Royal Navy reabsorbed the Fleet Air Arm from the RAF in 1937.

35. Barlow, *Revolt of the Admirals*, 30.

36. Medaris and Gordon, *Countdown for Decision*, 45–8, 53–4.

37. Barlow, *Revolt of the Admirals*, 52–5; Donovan, *Tumultuous Years*, 53–65.

38. Millis and Duffield, *Forrestal Diaries*, 389–95, 476–9.

39. Harrington, *Berlin on the Brink*, 111, 119–23; Craig and Radchenko, *Atomic Bomb and the Origins of the Cold War*, 128–30; Borowski, *Hollow Threat*, 123–9; Millis and Duffield, *Forrestal Diaries*, 456–8; Williamson and Rearden, *Origins of U.S. Nuclear Strategy*, 85–90. See also Rosenberg, "Origins of Overkill," 12–6.

40. Harrington, *Berlin on the Brink*, 123–5; Borowski, *Hollow Threat*, 123–4; McCullough, *Truman*, 603.

41. Sheehan, *Fiery Peace in a Cold War*, 130–6. See also Coffey, *Iron Eagle*; Tillman, *LeMay*; LeMay and Kantor, *Mission with LeMay*.

42. Borowski, *Hollow Threat*, 163–8; LeMay and Kantor, *Mission with LeMay*, 432–9. Emphasis original.

43. Goldberg, *History of the United States Air Force*, 122, 202–8; Hansen, *The Bird Is on the Wing*, 110–8.

44. Borowski, *Hollow Threat*, 154–5. Brown, *Flying Blind*, 68–160, contains thorough accounts of the development of the B-36 and B-47 bombers. Later versions of the B-36 were equipped with two jet engines to complement its six propeller engines.

45. Borowski, *Hollow Threat*, 191–2; Rosenberg, "Origins of Overkill," 16. Werrell's history of strategic bombing, *Death from the Heavens*, contains an excellent summary of the personnel, political, and technical issues facing SAC (155–72). For the Soviet side of this matter, see Holloway, *Stalin and the Bomb*, 227–45.

46. Rearden, *History of the Office of the Secretary of Defense*, 407–9.

47. Borowski, *Hollow Threat*, 218.

CHAPTER 3: Missiles in the Postwar Years

1. See Lasby, *Project Paperclip*; Gimbel, *Science, Technology, and Reparations*.

2. Guided Missiles Committee, OSRD, "A National Program for Guided Missiles," with covering letter from Bradley Dewey, November 21, 1945, in RG 341, Guided Missiles Branch, Box 115, NA.

3. Joint Committee on New Weapons and Equipment, JCS, "A Proposed National Program for Development of Guided Missiles," February 5, 1946, and Robert Patterson to JCS, "Proposed National Program for the Development of Guided Missiles," April 1, 1946, in RG 165, Papers of War Department Special and General Staffs, Box 565. "Top Secret American British Canadian (ABC) Correspondence File Relating to Organizational Planning and General Combat Operations during World War II and the Early Post-War Period 1940–48," File 471.6, October 7, 1943, Sec 1-B, NA; Adm. William Leahy to the Secretary of War and Secretary of the Navy, "A Proposed National Program for Development of Guided Missiles," March 23, 1946, in RG 341, Guided Missiles Branch, Box 93, File AAF Policy 1946, NA. Leahy's position was the

equivalent of the chairman of the JCS. That title would come into use with Leahy's successor, Gen. Omar Bradley, starting in 1949.

4. Stilwell et al., *Report of War Department Equipment Board*, 10–12, 68–70.

5. US Army Ordnance Corps and General Electric Company, "Hermes Guided Missile Research and Development Project," September 25, 1959. NASA History Office, NASA Headquarters, Washington, DC; Malina, "Origins of JPL," in Emme, *History of Rocket Technology*, 60–6; Neufeld, *Von Braun*, 206–15; Koppes, *JPL and the American Space Program*, 18–22; Stine, *ICBM*, 118–20.

6. Von Braun's story is told in many biographies, the best of which is Neufeld's *Von Braun*.

7. Neufeld, *Von Braun*, 238–40.

8. Heppenheimer, *Facing the Heat Barrier*, 91–6; "Hermes Guided Missile Research and Development Project," prepared for Technical Liaison Branch, Office of the Chief of Ordnance, Department of the Army, September 25, 1959, in NASA Headquarters History Office Historical Reference Collection; Neufeld, *Von Braun*, 217, 238–9, 249; Miller, *X-Planes*, 112–21. The navy built an antiaircraft missile named Talos that used ramjet engines. Talos began flying in 1953 and was deployed on the fleet between 1958 and 1980.

9. Neufeld, *Von Braun*, 219–20, 238–9.

10. Neufeld, *Von Braun*, 219.

11. For more on the space experiments of this time, see DeVorkin, *Science with a Vengeance*. Gainor, *To a Distant Day*, 94–8.

12. Siddiqi, "Germans in Russia," 120–43; Zaloga, *Target America*,113–21; Siddiqi, *Red Rockets' Glare,* 196–240.

13. Siddiqi, "Germans in Russia"; Zaloga, *Target America*, 113–21.

14. Zaloga, *Target America*, 121–4.

15. House of Representatives, Committee on Government Operations, *Organization and Management of Missile Programs*, 431–4; Werrell, *Death from the Heavens*, 249; Wyndham D. Miles, "The Polaris," in Emme, *History of Rocket Technology,* 162–5.

16. Rosen, *Viking Rocket Story*; DeVorkin, *Science with a Vengeance*, 175–82. Two additional Vikings were flown in Project Vanguard after Viking ended in 1955.

17. Robert Perry, "The Atlas, Thor, Titan and Minuteman," in Emme, *History of Rocket Technology*, 142; Collins, *Cold War Laboratory*, 9–16; Hanle, "Near Miss," 50–6. For more on Arnold, see his biography, Coffey, *Hap*, and his autobiography, *Global Mission*.

18. Arnold, *Third Report of the Commanding General*, 67–8.

19. The Scientific Advisory Group included nine scientists working full time, twenty-two experts working part time, and six expert military officers rounding out the team. Gen. H. H. Arnold to Dr. Theodore von Kármán, "AAF Long Range Development Program," November 7, 1944, in Spires, *Orbital Futures*, 166–8. See also Gorn, *Prophecy Fulfilled*.

20. See Gorn's biography of von Kármán, *Universal Man*. Von Kármán chaired the group, Hugh Dryden was vice chair, and other full-time staff included Tsien Hsue-shen, who worked on rocket and jet engines, and future laureate of the Nobel Prize in physics Luis W. Alvarez, who was in charge of radar but didn't contribute to the group's final report. Further information on von Kármán's life and work is contained in Hanle, *Bringing Aerodynamics to America*.

21. Theodore von Kármán, Director, Army Air Forces Scientific Advisory Group, *Where We Stand,* in Gorn, *Prophecy Fulfilled*, 17–37.

22. Von Kármán, *Where We Stand*.

23. Von Kármán, *Where We Stand*.

24. See Lonnquest, "Face of Atlas," 23–4; Beard, *Developing the ICBM*, 54–63.

25. Von Kármán, *Where We Stand*; AAF Scientific Advisory Group, *Science: The Key to Air Supremacy*, vol. 1, *Toward New Horizons*, in Gorn, *Prophecy Fulfilled*, 89–186.

26. The thirty technical reports covered areas such as aerodynamics and aircraft design, aircraft power plants, aircraft fuels and propellants, explosive and terminal ballistics, radar, communications and weather issues, and aeromedicine. The expert authors included Tsien Hsue-shen, then one of America's top rocket engineers and later the father of communist China's space and rocket programs, who wrote on propulsion methods, including ramjets and rockets; William H. Pickering, future director of the Jet Propulsion Laboratory, who covered automatic control of guided missiles; Lee A. DuBridge, a future president of Caltech and presidential science advisor, who wrote on communications; and physician William R. Lovelace II, who covered aerospace medicine.

27. Hugh L. Dryden, "Present State of the Guided Missile Art," in von Kármán et al., *Toward New Horizons*, December 15, 1945, in RG 341, Guided Missiles Branch, Box 136, NA.

28. Dryden, "Present State of the Guided Missile Art." James H. Capshew wrote in "Engineering Behavior: Project Pigeon, World War II, and the Conditioning of B. F. Skinner." *Technology and Culture* 34, no. 4 (October 1993): 835–57, that Project Pigeon was canceled because of the vast differences in outlook between Skinner and the NRDC engineers, including Dryden, rather than because of technical problems. Well-known physicist George Gamow questioned at the time whether inertial guidance systems, which operate without outside help, were physically possible, according to RAND physicist Bruno Augenstein in his interview with Joseph Tatarewicz and Martin Collins, July 28, 1986, RAND History Project, National Air and Space Museum, Smithsonian Institution, Washington, DC.

29. Gen. Crawford to Commanding General, Air Technical Services Command, "Guided Missiles of the German A-9 and A-10 Type," September 28, 1945, in RG 341, Guided Missiles Branch, Box 134, File "Special Inter Departmental Board," NA.

30. Futrell, *Ideas, Concepts, Doctrine*, 219–20.

31. AAF Scientific Advisory Group, *Science: The Key to Air Supremacy*, in Gorn, *Prophecy Fulfilled*, 120.

32. Heppenheimer, *Facing the Heat Barrier*, 91–6; "Hermes Guided Missile Research and Development Project," prepared for Technical Liaison Branch, Office of the Chief of Ordnance, Department of the Army, September 25, 1959, in NASA Headquarters History Office Historical Reference Collection; Neufeld, *Von Braun*, 217, 238–9, 249; Miller, *X-Planes*, 112–21.

33. Heppenheimer, *Facing the Heat Barrier*, 197–8; Neufeld, *Von Braun*, 249.

34. Reports quoted in Gorn, *Prophecy Fulfilled*, 59–61, 125, 178. Tsien Hsue-shen wrote a monograph for *Where We Stand* on nuclear fuels for aircraft propulsion.

35. The President's Air Policy Commission, *Survival in the Air Age*, 80; Maj. Gen. E. E. Partridge, Acting Deputy Chief of Staff, Operations to Secretary of the Air Staff, "Data for the President's Air Policy Commission Concerning Guided Missiles," Routing and Record Sheet, October 28, 1947, in Self, *History of the Development of Guided Missiles*.

36. Schwartz, *Atomic Audit*, 123–6; Miller, *X-Planes,* 98–111; Brown, *Flying Blind*, 193–210; Herken, "Flying Crowbar," 28–33.

37. Basalla, *Evolution of Technology*, 176–85. Basalla also raised the case of atmospheric railways, an ultimately unsuccessful technology tried in Britain in the 1930s where trains were driven not by engines but pistons inside a pneumatic tube laid between the rails.

38. Gorn, *Harnessing the Genie*, 39–42, 134–40. See also Gorn's introductory essay in *Prophecy Fulfilled*.

39. For more on in-house development in the US military during these years, see Lassman, *Sources of Weapon Systems Innovation*.

40. For a discussion of how historians of technology see that technological systems (such as missiles) are determined by social, economic, and political forces in addition to technological inputs, see Hughes, "Evolution of Large Technological Systems," 51–82.

41. Neufeld, *Von Braun*, 220, 365; Swenson et al., *This New Ocean*, 23–6.

42. Neufeld, *Von Braun*, 124, 134; Zaloga, *Target America*, 115–6. In 1959, the Soviet government placed control of all ballistic missiles under their own branch of the Soviet military, the newly created Strategic Missile Forces.

43. Lt. Gen. Joseph T. McNarney to Commanding General, Army Ground Forces, "Guided Missiles," October 2, 1944, in Spaatz Collection, Box 263, R&D 2, Library of Congress. Ironically, McNarney was an AAF officer. The directive applied only inside the War Department and did not affect the US Navy. Rosenberg, *The Air Force and the National Guided Missile Program*, 17–23; Hanle, "Near Miss," 86–93.

44. Rosenberg, *The Air Force and the National Guided Missile Program*, 23–30.

45. Eisenhower discussed the German missiles during the war in his *Crusade in Europe*, 229–30, 258–60, 328. Rosenberg, *The Air Force and the National Guided Missile Program*, 30–1. See also Baucom, "Eisenhower and Ballistic Missile Defense," 4–17. There is an extensive literature on Eisenhower, and works on Eisenhower as president are cited in chapters 6 and 7 in this book.

46. Brig. Gen. Alden R. Crawford to Maj. Gen. E. M. Powers, "Guided Missiles," February 28, 1946, in RG 341, Guided Missiles Branch, Box 142, File "GM Policy within USAF 47 and 48," NA; Chief of Air Staff to the Chief of Staff, Draft of Proposed Memorandum, "Memorandum of 2 October 1944, from the Chief of Staff, Assigning Guided Missiles Development Responsibility," October 8, 1945, plus three addenda: "Tab A: Guided Missiles Will Be Pilotless Aircraft with Airframes Built by Aeronautical Manufacturers"; "Tab B: The A.A.F. Has the Basic Experience on Guided Missiles and Guided Missile Component Development"; and "Tab C: High Priority Long-Term AAF Guided Missiles Program," in RG 341, Guided Missiles Branch, Box 142, File "Policy from Higher Authority," NA. Col. V. A. Stace, Acting Chief, Guided Missiles Branch, to Chief, Research and Engineering Division, "Desired Transfer from ASF of Guided Missiles Development Responsibilities," December 6, 1945, in RG 341, Guided Missiles Branch, Box 142, File "Policy from Higher Authority," NA.

47. Rosenberg, *The Air Force and the National Guided Missile Program*, 2–4.

48. Collins, *Cold War Laboratory*, 216–7; Futrell, *Ideas, Concepts, Doctrine*, 481. LeMay was appointed commander of USAF forces in Europe in October 1947, and the following year he became commander of the Strategic Air Command.

49. Futrell, *Ideas, Concepts, Doctrine*, 481.

50. Lt. Gen. N. F. Twining to AAF Commanding General, Draft Memo, "Guided Missiles," undated but probably early 1946, in RG 341, Guided Missiles Branch, Box 142, File "GM Policy within USAF 47 and 48," NA. Twining was a future US Air Force chief of staff and chairman of the Joint Chiefs of Staff.

51. Brig. Gen. Alden R. Crawford to Maj. Gen. E. M. Powers, "Army Air Force Long Term Guided Missiles Program," September 13, 1945, in RG 341, Guided Missiles Branch, Box 144, File "Policy within A-4," NA. In 1947, Wright Field was combined with nearby Patterson Field to create Wright-Patterson Air Force Base in 1948, and it remains the home of USAF research staff.

52. Brig. Gen. H. I. Hodes to Commanding Generals, Army Air, Service and Ground Forces, "Policy on Research and Development of Guided Missiles," February 13, 1946, in RG 341, Guided Missiles Branch, Box 142, File "GM Policy within USAF 47 and 48," NA.

53. Gen. Crawford to Commanding General, Army Air Forces, "Policy on Research and Development of Guided Missiles," March 26, 1946, in RG 341, Guided Missiles Branch, Box 93, File "AAF Policy 1946," NA; Rosenberg, *The Air Force and the National Guided Missile Program*, 33.

54. Carroll L. Zimmerman, Chief, Operations Analysis Section, to Chief of Staff, "Assignment of Cognizance and Control of the Pilotless Aircraft (Guided Missile) Program," May 20, 1946, in RG 341, Guided Missiles Branch, Box 93, File "AAF Policy 1946," NA.

55. Maj. Gen. Curtis LeMay to General Spaatz, "Guided Missiles Policy," May 22, 1946, and Gen. Carl Spaatz to Maj. Gen. Donald Wilson, May 29, 1946, in Spaatz Collection, Box 263, Research and Development File 2, Manuscript Division, Library of Congress; Rosenberg, *The Air Force and the National Guided Missile Program*, 34–5; Biographical Information from Finding Aid on Henry S. Aurand, Dwight D. Eisenhower Presidential Library, Abilene, Kansas.

56. "Prepared Briefing for General Aurand," undated but between mid-May and July 11, 1946, in RG 341, Guided Missiles Branch, Box 93, File "AAF Policy 1946," NA.

57. Gens. LeMay and Sayler to Director of Research and Development, War Department, Draft Memorandum for Signature, "Coordination of Guided Missile Development," undated, and Maj. Gen. LeMay to Gen. Carl Spaatz, "Guided Missiles," September 20, 1946, both in RG 341, Guided Missiles Branch, Box 93, File "AAF Policy 1946," NA; Rosenberg, *The Air Force and the National Guided Missile Program*, 35.

58. Rosenberg, *The Air Force and the National Guided Missile Program*, 35–6.

59. Hanson W. Baldwin, "Rocket Program Splits Services; Army Air Forces Seeking Control," *New York Times*, May 12, 1946, 1.

60. "Guided Missile Contract Data Demanded," *Washington Post*, August 19, 1946.

61. Rosenberg, *The Air Force and the National Guided Missile Program*, 36–7; Lt. Gen. T. T. Handy to Gen. D. E. Eisenhower, "Personal to Eisenhower from Handy," October 3, 1946, in RG 341, Guided Missiles Branch, Box 93, File "AAF Policy 1946," NA.

62. Handy to Eisenhower, "Personal to Eisenhower."

63. Brig. Gen. H. I. Hodes to Commanding Generals of Army Forces, "Guided Missiles," October 7, 1946, in RG 341, Guided Missiles Branch, Box 142, File "GM Policy within USAF 47 and 48," NA.

64. Maj. Gen. H. S. Aurand to Commanding General, AAF, Chief of Ordnance, and Chief Signal Officer, "Review of Guided Missiles Projects," October 10, 1946, in RG 341, Guided Missiles Branch, Box 142, File "GM Policy within USAF 47 and 48," NA. The signal corps was involved in developing communications equipment for missiles.

65. Maj. Gen. Curtis E. LeMay, Statement for Guided Missiles Press Conference, undated but shortly after November 26, 1946, part of an undated package of materials for the media on guided missiles, in RG 341, Guided Missiles Branch, Box 103, File "Guided Missiles Material," NA; Rosenberg, *The Air Force and the National Guided Missile Program*, 38.

66. Gen. Carl Spaatz to the Deputy Chief of Staff, "Policy on Research and Development of Guided Missiles," March 4, 1946, in RG 341, Guided Missiles Branch, Box 93, File "AAF Policy 1946," NA; Rosenberg, *The Air Force and the National Guided Missile Program*, 45–9; Baldwin, "Rocket Program Splits Services," 1.

67. Document attached to Maj. Gen. Curtis LeMay to Executive Officer, Office of the Assistant Secretary of War for Air, "Guided Missiles Program," July 18, 1947, in RG 341, Guided Missiles Branch, Box 134, File "Surface to Surface Consolidated MX-774," NA.

68. Rosenberg, *The Air Force and the National Guided Missile Program*, 36–8.

69. Lt. Col. John F. O'Neill, Memorandum for Record, "Air Force Administration of Army Ordnance Guided Missile R & D Projects," July 18, 1949, in RG 341, Guided Missiles Branch, Box 115, NA.

70. "Excerpt from Army-Air Force Agreements as to Initial Implementation of the National Security Act of 1947 dtd 15 September 1947," in RG 341, Guided Missiles Branch, Box 142, File "GM Policy within USAF 47 and 48," NA; Rosenberg, *The Air Force and the National Guided Missile Program*, 40–5.

71. Lt. Gen. H. S. Aurand to Chief of Staff, USAF, "Guided Missiles Research and Development, U.S. Army," March 3, 1948; Lt. Gen. H. A. Craig to Chief of Staff, US Army, "Guided

Missiles Research and Development, Department of the Army," March 20, 1948; and Maj. Gen. A. C. McAuliffe to Chief of Staff, USAF, "Guided Missiles Research and Development, Department of the Army," undated, all in RG 341, Guided Missiles Branch, Box 142, File "GM Policy within USAF 47 and 48," NA.

72. Rosenberg, *The Air Force and the National Guided Missile Program*, 49–53.

73. Wolk, *Struggle for Air Force Independence*, 238–41; Barlow, *Revolt of the Admirals*, 117, 120–1.

74. Collins, *Cold War Laboratory*, 36–8, 156, 216–7.

CHAPTER 4: Tentative Steps on Rockets

1. Rosenberg, *The Air Force and the National Guided Missile Program,* 9–10; Hanle, "Near Miss," 314–37.

2. Self, *History of the Development of Guided Missiles*, 1–4.

3. See Kelsey D. Atherton, "FYI: What Are Cruise Missiles, and How Do They Work?" *Popular Science*, August 29, 2013, https://www.popsci.com/technology/article/2013-08/fyi-cruise-missiles.

4. This is an example of what sociologist Trevor Pinch called testing as performances to promote a certain technology or a particular technology provider. "'Testing—One, Two, Three,'" 25–41.

5. Col. John G. Moore to Commanding General, Air Technical Services Command, "Guided Missiles," January 11, 1946, in document collection appended to Self, *History of Missile Development*, 26–30.

6. Rosenberg, *The Air Force and the National Guided Missile Program,* 85–95.

7. The decree dated May 13 is reproduced in Chertok, *Rockets and People*, 2:10–15; Siddiqi, *Challenge to Apollo*, 25, 33–40.

8. Siddiqi, *Red Rockets' Glare*, 222–3, 232–40, 245–7; Zaloga, *Target America*, 115–8.

9. Zaloga, *Target America*, 63–79; idem, *Kremlin's Nuclear Sword*, 12–6, 35–9; Siddqi, *Challenge to Apollo*, 60–1; idem, *Red Rockets' Glare*, 286–7. Many accounts, including Holloway, *Stalin and the Bomb*, 247, have stated that the Soviet ICBM program began at the April 1947 meeting, based mainly on the post-Sputnik writings of Tokaty, who had little direct knowledge of the Soviet missile program. Tokaty has also been identified as Grigory Tokaty-Tokayev. Siddiqi's description of the Stalin-Korolev meeting in *Challenge to Apollo* is based on Korolev's own accounts.

10. Zaloga, *Target America*, 79–88; Holloway, *Stalin and the Bomb*, 227–45; Siddiqi, *Red Rockets' Glare*, 271–2. Kaplan, *Wizards of Armageddon*, 155–73, discusses the origins of the "bomber gap" in the United States in some detail, including its relationship to the "missile gap" controversy that followed. See also Werrell, *Death from the Heavens*, 176–9, 213; Leighton, *Strategy, Money and the New Look*, 379–88; and Chun, "Winged Interceptor," 44–59.

11. Zaloga, *Target America*, 125–32; Siddqi, *Challenge to Apollo*, 61, 71–88; idem, *Red Rockets' Glare*, 248–60.

12. Testimony of Gen. Bernard Schriever, US Senate, *Hearings before the Preparedness Investigating Subcommittee*, 1637–8; testimony of Gen. Curtis LeMay, US House of Representatives, Subcommittee of the Committee on Appropriations, *Military Establishment Appropriation Bill for 1948*, 479. For more on procurement practices of the USAF and its predecessors, see Johnson, *United States Air Force and the Culture of Innovation*, 27–58; Hanle, *Bringing Aerodynamics to America*, 1–2; and Lassman, *Sources of Weapon Systems Innovation*, 67–93.

13. The officials quoted in this study refer to missile ranges in miles. To further complicate matters, US military officials usually use nautical miles, which are longer than the statute miles commonly used in the English system of measures. A nautical mile (nm) equals 1.15 statute miles, or 1,852 meters. This book uses nautical miles for missile ranges, so 175 nm

equals 324 km, 500 nm equals 926 km, 1,500 nm equals 2,778 km, and 5,000 nm equals 9,260 km. Most ICBMs are designed to fly 5,000 nm (9,260 km) or farther.

14. Rosenberg, *The Air Force and the National Guided Missile Program*, 74–7; Krudener, *History of Ballistic Missiles Site Activation*, 4–6; Collins, *Cold War Laboratory*, 41–52.

15. Chapman, *Atlas*, 27–9.

16. Rosenberg, *The Air Force and the National Guided Missile Program*, 77–82; Futrell, *Ideas, Concepts, Doctrine*, 219–21; Beard, *Developing the ICBM*, 89–91.

17. Maj. Gen. B. W. Chidlaw to Commanding General, AAF, "AAF Guided Missiles Program," May 6, 1947, in Self, *History of Missile Development*.

18. "Exhibit 'A' Subject: AAF Guided Missiles Program," attached to letter from Maj. Gen. B. W. Chidlaw, Deputy Commanding General, Engineering, May 6, 1947, in Self, *History of Missile Development*; Futrell, *Ideas, Concepts, Doctrine*, 482.

19. Chapman, *Atlas*, 56.

20. Chapman, *Atlas*, 29–34.

21. Neufeld, *Ballistic Missiles in the United States Air Force*, 45, 49. The unexpended funds came from the original contract and another $493,000 the air force added to Convair's contract in June 1946.

22. Col. R. J. Minty, "Evaluation of Proposal—Report No. ZP-48-35003," January 4, 1949; Col. John H. Carter, Routing and Record Sheet, "Evaluation of CVAC 1,000 Mile Range Missile," February 28, 1949, both in RG 341, 127, File "MX-774 Convair Firing TWX's and Weekly Progress Reports," NA. Maj. Gen. Powers to Symington, "Consolidated Vultee Guided Missile Proposal," December 21, 1949, RG 341, Guided Missiles Branch, Box 134, File "Surface to Surface Consolidated MX-774," NA.

23. Lt. Col. Charles Terhune to Brig. Gen. D. L. Putt, "Consolidated-Vultee Proposal for a 1,000 Mile Rocket-Powered Surface to Surface Missile," February 25, 1949, and Lt. Col. Charles Terhune to Brig. Gen. D. L. Putt, "Consolidated-Vultee Proposal for a 1,000 Mile Rocket-Powered Surface to Surface Missile," March 3, 1949, in RG 341, Guided Missiles Branch, Box 127, File "MX-774 Convair Firing TWX's and Weekly Progress Reports," NA.

24. The WAC Corporal was a liquid-fueled rocket developed by the Jet Propulsion Laboratory at Caltech, and the navy developed the Aerobee sounding rocket as a larger version of the WAC Corporal. The Bumper was a two-stage rocket combining the V-2 and the WAC Corporal. For more on rockets and upper atmosphere research, see DeVorkin, *Science with a Vengeance*, 167–82; idem, "Organizing for Space Research," 1–24.

25. Lt. Col. Charles H. Terhune to Brig. Gen. D. L. Putt, "A Proposed Extension of Project MX-774," March 23, 1949, in RG 341, Guided Missiles Branch, Box 127, File "MX-774 1949 and 1950 (Consolidated) Surface to Surface," NA. Rear Adm. D. V. Gallery, Assistant Chief of Naval Operations for Guided Missiles, "MX-774 Viking," March 22, 1949, RG 156, Office of the Chief of Ordnance, Records Relating to the Army Guided Missiles Program, Box 14, NA; Beard, *Developing the ICBM*, 65–7.

26. Heppenheimer, "Navaho Program," 4–17; Miller, *X-Planes,* 134–41. For more on Navaho, see Werrell, *Evolution of the Cruise Missile*; Dale D. Myers, "The Navaho Cruise Missile: A Burst of Technology" (presented at the 42nd Congress of the International Astronautical Federation, Montreal, October 5–11, 1991); USAF Historical Program, *The Development of the Navaho Guided Missile 1945–1953*, probably 1954, NASA Headquarters History Office, Historical Reference Collection.

27. Draft Inter-Office Memorandum, possibly from Maj. Cole to Brig. Gen. D. L. Putt, "Proposed Extension of MX-774 by CONVAIR," April 14 ,1949, with routing slips dated March 22 and 30, 1949, in RG 341, Guided Missiles Branch, Box 127, File "MX-774 Convair Firing TWX's and Weekly Progress Reports," NA; Beard, *Developing the ICBM*, 67.

28. Swenson et al., *This New Ocean*, 22–7; Hughes, "Evolution of Large Technological Systems," 68–70.

CHAPTER 5: Missiles in Question

1. Zachary, *Endless Frontier*, 113, 241; Hanle, "Near Miss," 68–80.

2. Joint Research and Development Board, undated, probably fall or winter, 1946–7, in RG 156, Office of the Chief of Ordnance, Records Relating to the Army Guided Missiles Program, Box 5, NA; Rosenberg, *The Air Force and the National Guided Missile Program*, 54–6. See also Baxter, *Scientists against Time*, 28–30; Bush, *Pieces of the Action*, 52. Hanle, "Near Miss," 70–4, 330, wrote that the GMC was formed in part because of the lack of cooperation between NDRC and the USAAF over guided weapons such as the JB-2. The GMC had representatives from the army, navy, and agencies such as OSRD and NACA.

3. Sherry, *Preparing for the Next War*, 141–58. Zachary, *Endless Frontier*, 250, 307, 317–8; Kevles, "Scientists, the Military, and the Control of Postwar Defense Research," 20–47. In 1950, Congress finally passed legislation creating the National Science Foundation, which controlled less money and had more political control than Bush's report had proposed. The NSF had no involvement in military research, contrary to the report's recommendations.

4. Schnabel, *History of the Joint Chiefs of Staff*, 64–5.

5. US Senate, Special Committee on Atomic Energy, *Hearings before the Special Committee on Atomic Energy*, 178–80.

6. Zachary, *Endless Frontier*, 228, 291, 334–5.

7. Bush, *Modern Arms and Free Men*, 83–4.

8. Bush, *Modern Arms and Free Men*, 83–4.

9. Bush, *Modern Arms and Free Men*, 83–4.

10. Bush, *Modern Arms and Free Men*, 71–89; Neufeld, *Von Braun*, 239.

11. Zachary, *Endless Frontier*, 316–9, 337.

12. Bulkeley, *Sputniks Crisis*, 41; Kalic, "U.S. Presidents and the Militarization of Space," 41–2.

13. Futrell, *Ideas, Concepts, Doctrine*, 481–2.

14. Collins, *Cold War Laboratory*, 29–54.

15. Roland, *Military-Industrial Complex*, 21. For more on RAND, see also Smith, *RAND Corporation*; Kaplan, *Wizards of Armageddon*.

16. Abella, *Soldiers of Reason*, 3–6, argued that RAND has also changed the way Americans and others see and interact with their governments. See also Chalmers Johnson, "A Litany of Horrors: America's University of Imperialism," TomDispatch.com, April 29, 2008, http://www.tomdispatch.com/post/174925/chalmers_johnson_teaching_imperialism_101. Collins, *Cold War Laboratory*, 217, wrote that "the military services stood at the center of a reordering of American political and economic life."

17. Hall, "Early U.S. Satellite Proposals," 410–34. The ambition of the BuAer plan can be illustrated by the fact that a single-stage orbital launch vehicle has yet to be developed.

18. Captain W. F. Cogswell, Navy Bureau of Aeronautics, Memorandum to Assistant Chief for Research, Development and Engineering, March 11, 1946, in RG 341, Guided Missiles Branch, Box 133, File "Satellite Project," NA.

19. Hall, "Early U.S. Satellite Proposals," 414–8; Collins, *Cold War Laboratory*, 74–5; Abella, *Soldiers of Reason*, 13–20. See also Davies and Harris, *RAND's Role in the Evolution of Balloon and Satellite Observation Systems*, 6–9.

20. Project RAND, *Preliminary Design of an Experimental World-Circling Spaceship*, 9–10; Seitz and Taub, "Louis N. Ridenour," 20–1; Day, *Lightning Rod*, 23–9. Ridenour's active involve-

ment with missiles began with this RAND study and continued until his death in 1959 at age 47, when he was a vice president of Lockheed Aircraft Corp.

21. Col. M. F. Cooper, Memorandum for Record, "Satellite Project," May 21, 1946, in RG 341, Guided Missiles Branch, Box 133, File "Satellite Project," NA.

22. Hall, "Early U.S. Satellite Proposals," 415, 420–2.

23. Brig. Gen. William L. Richardson, Memorandum for Record, "Earth Satellite Vehicle," May 13, 1947, in RG 341, Guided Missiles Branch, Box 133, File "Satellite Project," NA.

24. Brig. Gen. Alden Crawford to Chief of Staff, USAF, "Project RAND, Satellite Vehicle," December 8, 1947, and Lt. Col. Charles Terhune to Col. Millard Young, "Rand (Satellite) Policy," in RG 341, Guided Missiles Branch, Box 133, File "Satellite Project," NA; Research and Development Board to the Committee on Guided Missiles, "Earth Satellite Vehicle," January 7, 1948, with attached Status Report on Earth Satellite Vehicle, January 15, 1948, in RG 341, Guided Missiles Branch, Box 105, File "Agenda of 10th Meeting of GM Committee," NA.

25. Futrell, *Ideas, Concepts, Doctrine*, 488. Unsigned Memorandum for Record, "Satellite Vehicles," January 16, 1948; Unsigned Memorandum for the Vice Chief of Staff, "Earth Satellites Vehicles," January 8, 1948, with attached "Statement of Policy for a Satellite Vehicle," in RG 341, Guided Missiles Branch, Box 133, File "Satellite Project," NA.

26. Brig. Gen. D. L. Putt, Lecture, National War College, January 11, 1949, in RG 341, Guided Missiles Branch, Box 131, File "Plans 1949–50," NA.

27. Rearden, *History of the Office of the Secretary of Defense*, 96–103.

28. Zachary, *Endless Frontier*, 335–41. See also Bush, *Pieces of the Action*, 67.

29. Futrell, *Ideas, Concepts, Doctrine*, 275–6. The task force, headed by Ferdinand Eberstadt, examined the United States' intelligence apparatus as part of the Hoover Commission on the organization of the US government executive branch. Rearden, *History of the Office of the Secretary of Defense*, 101.

30. Committee on Guided Missiles, Joint Research and Development Board, "Publicity Release: Submitted to the Committee at its First Meeting," undated, in RG 156, Office of the Chief of Ordnance, Records Relating to the Army Guided Missiles Program, Box 5, NA; Zachary, *Endless Frontier*, 318.

31. James Forrestal, "Directive: Research and Development Board," December 18, 1947; L. R. Hafstad, Research and Development Board, "Draft Directive: Formation of a Committee on Guided Missiles," January 23, 1948, in RG 341, Guided Missiles Branch, Box 105, NA. The draft was ratified at the tenth meeting of the existing guided missiles committee on February 3, 1948. The minutes are located in the same place as the directive.

32. Hafstad, "Draft Directive"; Zachary, *Endless Frontier*, 335.

33. Quoted in Rosenberg, *The Air Force and the National Guided Missile Program*, 110.

34. Hughes, "Evolution of Large Technological Systems," 51–2.

35. Karl F. Kellerman, Executive Director, Guided Missiles Committee, RDB, to Members of the Ad Hoc Subcommittee on Long Range Rockets, "Membership and Task of the Ad Hoc Subcommittee on Long Range Rockets," June 24, 1948, in RG 156, US Army, Office of the Chief of Ordnance, Records Relating to the Army Guided Missiles Program, Box 7, File "Ad hoc Subcommittee–GM Committee–RDB (Long Range Rocket)," NA.

36. "Report of Ad Hoc Subcommittee on Long Range Rockets to the Committee on Guided Missiles," RDB, July 20, 1948, and Ad Hoc Subcommittee on Long Range Rockets, Minutes of the 1st Meeting Held 20 July 1948 in Rm 3D 564 the Pentagon, in RG 156, US Army, Office of the Chief of Ordnance, Records Relating to the Army Guided Missiles Program, Box 7, File "Ad hoc Subcommittee–GM Committee–RDB (Long Range Rocket)," NA.

37. Col. H. N. Toftoy to Major J. P. Taylor, "Long Range Rocket," October 6, 1948, in RG 156, US Army, Office of the Chief of Ordnance, Box 7, File "Ad hoc Subcommittee–GM Committee–RDB (Long Range Rocket)," NA; Bullard, *History of the Redstone Missile System*, 22; Rosenberg, *The Air Force and the National Guided Missile Program*, 109. Ultimately, Redstone had a range of only 200 miles.

38. Technical Evaluation Group, Committee on Guided Missiles, RDB, "The National Guided Missiles Program," May 20, 1949, in RG 218, Records of the Joint Chiefs of Staff, Box 107, File "JCS 334 Guided Missiles Comm (116–45) Sec 2," NA.

39. Capt. W. G. Lalor of JCS to Chairman, RDB, "Establishment of a Military Basis for Guided Missile Program Planning," October 26, 1949, in RG 341, Guided Missiles Branch, Box 110, File "Agenda, 21st meeting of GM cttee," NA.

40. Rosenberg, *The Air Force and the National Guided Missile Program*, 152–8.

41. After its role in facilitating ICBMs in the early 1950s, RAND continued to grow to the point where RAND and the people associated with it held great sway over all US military programs in the Kennedy administration, to the great annoyance of the air force. The USAF turned away from RAND for advice and to the Aerospace Corporation, a think tank similar to RAND but one more closely aligned to the USAF. See Abella, *Soldiers of Reason*, 132–42.

CHAPTER 6: Truman Moves on Missiles

1. Schilling, "Politics of National Defense: Fiscal 1950," in *Strategy, Politics and Defense Budgets*, discusses the debate in Congress and the administration over the FY 1950 budget in great detail.

2. Schillling, "Politics of National Defense," 113.

3. McCullough, *Truman*, 741–2; Barlow, *Revolt of the Admirals*, 173–7.

4. Schilling, "Politics of National Defense," 113.

5. The National Security Act also established the Central Intelligence Agency and the National Security Council. Millis and Duffield, *Forrestal Diaries*, 296–7; Parrish, *Behind the Sheltering Bomb*, 175–90.

6. Futrell, *Ideas, Concepts, Doctrine*, 483–4; McFarland and Roll, *Louis Johnson*, 188–204; Leffler and Westad, *Cambridge History of the Cold War*, 288–93. As president, Eisenhower expressed similar fears about the ability of the US economy to support massive military spending. Roland, *Military-Industrial Complex*, 3.

7. Barlow, *Revolt of the Admirals*, 215–94; Donovan, *Tumultuous Years*, 105–13; Boettcher, *First Call*, 172–86; Bradley, *General's Life*, 487–513; Rosenberg, *The Air Force and the National Guided Missile Program*, 120–2; Futrell, *Ideas, Concepts, Doctrine*, 258–9.

8. Documents from the 17th Guided Missiles Committee Meeting, June 1949, including Gordon Gray to Secretary of Defense, "Assignment of Responsibility for Guided Missile Operations and Development," May 16, 1949, responses from Louis Johnson, May 25, 1949, and committee papers from 17th item of 17th meeting, in RG 341, Guided Missiles Branch, Box 108, NA; Rosenberg, *The Air Force and the National Guided Missile Program*, 122–6.

9. Documents from 17th GMC meeting.

10. Karl Compton, Chairman, RDB, to Louis Johnson, June 2, 1949, in RG 341, Guided Missiles Branch, Box 110, File "Agenda, 22nd meeting of GM cttee," NA.

11. Briefing Sheet for the Chairman, Joint Chiefs of Staff for Item 7, meeting September 29, 1949, "J.S.C. 1620/B Assignment of Responsibility for Guided Missile Operations," with report by the Joint Strategic Plans Committee to the JCS, "Assignment of Responsibility for Guided Missile Operations," September 28, 1949, and Appendix to Enclosure "C" Draft Memorandum for the Secretary of Defense, in RG 218, Records of the Joint Chiefs of Staff, Box 107, File "JCS 334 Guided Missiles Comm (116–45) Sec 2," NA.

12. Gen. Omar Bradley to Secretary of Defense, "Assignment of Responsibility for Guided Missiles," November 17, 1949, in RG 341, Guided Missiles Branch, Box 109. Agenda, 20th Meeting of Guided Missile Committee, NA; Rosenberg, *The Air Force and the National Guided Missile Program,* 129–32.

13. Rosenberg, *The Air Force and the National Guided Missile Program*, 158–66; Neufeld, *Ballistic Missiles in the United States Air Force*, 60, 64.

14. Rosenberg, *The Air Force and the National Guided Missile Program*, 135–6.

15. Members of the Committee on Guided Missiles to the Chairman, Research and Development Board, "Guided Missile Program," August 26, 1949, in RG 341, Guided Missiles Branch, Box 104, File "Committee on Guided Missiles RDB," NA.

16. Clark B. Millikan to Acting Chairman, RDB, December 1, 1949; R. F. Rinehart to Clark Millikan, December 16, 1949, both in RG 341, Guided Missiles Branch, Box 110, File "Agenda, 22nd meeting of GM cttee," NA.

17. Memorandum for Mr. Symington, "Coordination and Control of Guide Missile Projects," December 20, 1949, in RG 341, Guided Missiles Branch, Box 131, File "Policy from Higher Authority," NA.

18. The board, which included Navy Under Secretary Dan A. Kimball, Army Assistant Secretary Archibald S. Alexander, and Rinehart of the RDB, met several times between December 21, 1949, and February 1, 1950, to draw up its recommendations. Memorandum for Messrs. Symington, Gray and Matthews, "Review of the National Guided Missiles Program," undated, with attachments of army, navy, and air force positions, February 8, 1950, in RG 341, Guided Missiles Branch, Box 121, File "Special Interdepartmental G.M. Board," NA; "Enclosure 1: History of Special Inter-Departmental Guided Missiles Board," undated, probably February 1950, in RG 218, Records of the Joint Chiefs of Staff, Box 108, File "JCS 334 Guided Missiles Comte (116-45) B.P," NA.

19. Maj. James R. Dempsey, Memorandum for Record, "Sequence of Events Concerning SIB," undated but about February 18, 1950, in RG 341, Guided Missiles Branch, Box 129, File "National Guided Missile Program 1950," NA.

20. Joint Chiefs of Staff, March 15, 1950; Wolf, *United States Air Force*, 213; Rosenberg, *The Air Force and the National Guided Missile Program*, 133–4, 151.

21. Joint Chiefs of Staff to the Secretary of Defense, March 15, 1950, in RG 218, Records of the Joint Chiefs of Staff, Box 107, File "JCS 334 Guided Missiles Comm (116-45) Sec 4," NA.

22. Thomas G. Lamphier Jr., Special Consultant to the Secretary of the Air Force, to Mr. Symington, "Analysis of JCS 1620/17 on Guided Missiles," March 22, 1950, in RG 341, Guided Missiles Branch, Box 129, File "National Guided Missile Program 1950," NA.

23. Craig and Radchenko, *The Atomic Bomb and the Origins of the Cold War*, 53–61, 75–110. These authors provide a nuanced view of Stalin's reaction to America's work on nuclear weapons, noting his refusal to appear impressed with US nuclear weapons as he raised the priority of Soviet nuclear weapons research.

24. For a thorough discussion of the Soviet nuclear weapons program and American reactions to it, see Gordin, *Red Cloud at Dawn*, 197–238.

25. Hansen, *US Nuclear Weapons*, 43–4.

26. Hansen, *US Nuclear Weapons*, 44–6.

27. For more background on the scientists' movements of the late 1940s, see Wang, *American Science in the Age of Anxiety*.

28. Chace, *Acheson*, 230–2; Rhodes, *Dark Sun*, 395–404.

29. Chace, *Acheson*, 232–6; Rhodes, *Dark Sun*, 404–5.

30. Chace, *Acheson,* 235–6; Rhodes, *Dark Sun*, 405–7.

31. Hubert E. Howard, Chair of Munitions Board, to the Secretary of Defense, "Guided Missiles," February 14, 1950, in RG 218, Records of the Joint Chiefs of Staff, Box 107, File "JCS 334 Guided Missiles Comm (116-45) Sec 3," NA. This memo and the Armed Forces Policy Council meeting are also discussed in chapter 3 in this volume. William S. White, "U.S. Willing to Discuss Atom With Soviet Union in U.N.," *New York Times*, February 14, 1950, 1. The two officers were Gen. Joseph McNarney of the USAF and Lt. Gen. Leroy Lutes, a former commander of the Army Service Forces.

32. R. F. Rinehart, Executive Secretary, RDB, to Chairman, RDB, "Guided Missiles Inquisition," February 28, 1950, in RG 330, Records of the Secretary of Defense, Box 465, File "100 Guided Missiles—Marriage Program," NA; Maj. James R. Dempsey, Memorandum for Record, "Sequence of Events Concerning SIB," undated but about February 18, 1950, in RG 341, Guided Missiles Branch, Box 129, File "National Guided Missile Program 1950," NA.

33. McCullough, *Truman*, 758–66; Chace, *Acheson*, 226–8, 236–7.

34. Borowski, *Hollow Threat*, 186–210; Miscamble, "Foreign Policy of the Truman Administration," 479–95; Herken, *Winning Weapon*, 329–32. Secretary of State Dean Acheson and State Department official Paul Nitze provided the main inspiration behind NSC-68. For more on NSC-68, see Paul Y. Hammond, "NSC-68: Prologue to Rearmament," in Schilling et al., *Strategy, Politics and Defense Budgets*, 267–378; Hogan, *Cross of Iron*, 291–314.

35. Dallek, *Lost Peace*, 327–32; McCullough, *Truman*, 820–6.

36. Condit, *Test of War*, 473–4.

37. Harry Truman to Secretary of Defense, November 13, 1948; W. Stuart Symington to Mr. Forrestal, "Request for Release of Guided Missies Procurement Funds–Project 180 (Supplemental) F.Y. 1948," with attachment, December 10, 1948, in RG 341, Guided Missiles Branch, Box 129, File "F-180 'Production' Program, Fy-48," NA. An online search of Truman's public papers at the Harry S. Truman Presidential Library turned up only a few references to missiles and rockets, mainly in budget messages, in a speech dedicating the Arnold Engineering Development Center, and in a press conference where Truman took questions about a leak of information related to the Matador Missile; see "Public Papers of Harry S. Truman, 1945–1953," Harry S. Truman Presidential Library and Museum (HSTL), accessed November 9, 2010, http://www.trumanlibrary.org/publicpapers/index.php. I could not find documents on file at the Truman Presidential Library indicating direct presidential involvement with missiles outside of those discussed in this chapter. Truman, *Memoirs*, 2:312, contains a mention of missiles. Here Truman lists guided missiles with atomic warheads along with other futuristic weapons.

38. Neustadt, *Presidential Power*, 173.

39. Cabell Phillips, "Why We're Not Fighting with Push Buttons," *New York Times Magazine*, July 16, 1950, 20.

40. Arthur Krock, "In The Nation: Origins and Developments of the Missile Program: II," *New York Times*, November 5, 1957, 30; Neufeld, *Ballistic Missiles*, 79–80.

41. Nichols, *Road to Trinity*, 281.

42. Dan A. Kimball, Under Secretary of the Navy, to the Secretary of Defense, August 21, 1950, in RG 330, Records of the Secretary of Defense, Box 465, File "100 Guided Missiles—Marriage Program," NA; Condit, *Test of War*, 474, wrote that the service secretaries also proposed a guided missiles board, but the new secretary of defense, George Marshall, rejected the idea because it would affect the powers of the joint chiefs.

43. Draft Memoranda Attached to Memorandum from Charles F. Brown, Counsel, to William Webster, Chairman, RDB, "Proposed Guided Missiles Project Organization," August 22, 1950, in RG 330, Records of the Secretary of Defense, Box 465, File "100 Guided Missiles—Marriage Program," NA.

44. Secretary Marshall to the Deputy Secretary of Defense, etc., "Establishment of the Director of Guided Missiles in the Office of the Secretary of Defense," and associated correspondence, in RG 330, Records of the Secretary of Defense, Box 465, File "100 Guided Missiles—Marriage Program," NA.

45. "K.T. Keller, Chrysler President From '35 to '50, Dies in London," *New York Times*, January 22, 1966, 29. For more on Keller's work at Chrysler, see "Motors: K.T," *Time*, October 16, 1939, and for more critical views, see Jefferys, *Management and Managed*; Moritz and Seaman, *Going for Broke*.

46. Testimony of K. T. Keller, in US House of Representatives, *Hearings before the Select Committee on Astronautics and Space Exploration*, 1498–519; Condit, *Test of War*, 474.

47. Neustadt, *Presidential Power*, 172.

48. Testimony of K. T. Keller, 1499–500.

49. Nichols, *Road to Trinity*, 280–1.

50. Nichols, *Road to Trinity*, 283–7.

51. K. T. Keller, Text of Address at War College, January 30, 1952, Keller Papers, National War College, Harry S. Truman Presidential Library and Museum (HSTL).

52. K. T. Keller to President Truman, July 10, 1951, Keller Papers, Guided Missiles, Correspondence—1950–52, HSTL. The Sparrow was later used by the USAF and the US Marine Corps in addition to the US Navy.

53. Director of Guided Missiles, "Report to the President on Status of Guided Missiles," July 10, 1951, Keller Papers, Guided Missiles, Correspondence—1950–52, HSTL. The Hermes-C1 missile became known as the Redstone missile.

54. K. T. Keller to President Truman, December 8, 1952, Keller Papers, Guided Missiles, Correspondence—1950–52, HSTL.

55. K. T. Keller to Dwight D. Eisenhower, May 12, 1953, and Eisenhower to Keller, May 14, 1953, in Harry S. Truman Post-Presidential Files, K. T. Keller, HSTL.

56. K. T. Keller to Harry S. Truman, November 6, 1959, in Harry S. Truman Post-Presidential Files, K. T. Keller, HSTL. Eisenhower's appointment book, which recorded the date of the lunch, is available from the Eisenhower Presidential Library, accessed April 21, 2010, https://www.eisenhower.archives.gov/research/online_documents/presidential_appointment_books/1953/June_1953.pdf.

57. Press release, Department of Defense, "K.T. Keller Completes Guided Missiles Assignment," undated but probably September 1953, Keller Papers, Guided Missiles, Correspondence—1953–54, HSTL.

58. K. T. Keller, "Final Report of the Director of Guided Missiles," September 17, 1953, Keller Papers, HSTL.

59. US Senate, *Hearings before the Preparedness Investigating Subcommittee, Committee on Armed Forces, Inquiry into Satellite and Missile Programs*, 584; Donnelly, *United States Guided Missile Program*, 10. Redstone served as the first stage of the launch vehicle for America's first satellite, Explorer 1, in 1958, and carried America's first two astronauts on their suborbital flights in 1961.

60. Bullard, *History of the Redstone Missile System*, 36–43. See also Lassman, *Sources of Weapon Systems Innovation*, 11–21.

61. Baucom, "Eisenhower and Ballistic Missile Defense"; idem, *U.S. Missile Defense Program*, 1–3. America's air defense system is also discussed in Schaffel, *Emerging Shield*, and Lonnquest and Winkler, *To Defend and Deter*.

62. Condit, *Test of War*, 475.

63. Truman made these comments in a syndicated newspaper column he wrote in October 1957 and reprinted in *Mr. Citizen*, 260–8. Almost identical comments from a newspaper

interview are contained in Homer Bigart, "Truman Is Caustic on Bipartisanship," *New York Times*, November 14, 1957, 1. Republican criticism of the Truman administration is contained in James Reston, "Politics and Defense," *New York Times*, November 22, 1957, 10. More Republican attacks on Truman's record on missiles can be found at the Dwight D. Eisenhower Presidential Library in the Papers of Bryce Harlow, Pre-accession Series, National Security File, Box 2. Keller's 1958 appearance before the House Committee on Astronautics and Space Exploration quoted in this chapter was no doubt intended to blunt criticism of Truman administration missile programs.

64. The best study of defensive missiles in this period is Bright, *Continental Defense in the Eisenhower Era*, which does not discuss Keller's role in the development of Nike or other missiles.

65. Roland, *Military-Industrial Complex*, 16–7; Donovan, *Tumultuous Years,* 324–5. Charles E. Wilson from General Motors was known as "Engine Charlie."

CHAPTER 7: The Revival of Ballistic Missiles

1. Col. M. C. Young, USAF Guided Missiles Presentation to Special Ad Hoc Committee of the JCS, January 25, 1949, in RG 341, Guided Missiles Branch, Box 115, NA. Emphasis in original. The estimated cost is similar to the $2 billion cost four years earlier for the Manhattan Project.

2. The RAND Corporation, "Project Rand: Recommendation to the Air Staff, A Re-evaluation of the Guided Missiles Program," October 14, 1949, with covering letter from F. R. Colbohm, Director, to Maj. Gen. Putt, in RG 341, Guided Missiles Branch, Box 132, File "Rand, 1945–50," NA. RAND had split from Douglas and became the RAND Corporation on November 1, 1948. Collins, *Cold War Laboratory*, 161; Davies and Harris, *RAND's Role,* 45.

3. R. F. Rinehart, Executive Secretary, Research and Development Board, to Dr. Karl Compton, "Summary of Presentation by RAND Corporation on Friday, October 14, 1949," October 18, 1949, in RG 330, Records of the Secretary of Defense, Box 465, File "100 Guided Missiles—Marriage Program," NA.

4. Majors Cole and Carey to Gen. D. L. Putt, "Project RAND Analysis of Ramjet Versus Rocket Propelled Strategic Guided Missiles," October 27, 1949, in RG 341, Guided Missiles Branch, Box 98, File "Boosters 1949–1950," NA; Heppenheimer, "The Navaho Program."

5. Cole and Carey to Gen. D. L. Putt, "Project RAND Analysis," October 27, 1949.

6. Krudener, *History of Ballistic Missiles Site Activation*, 16.

7. L. A. Hyland, Guided Missiles Committee, to William Webster, Chairman, RDB, September 14, 1950, in RG 330, Records of the Secretary of Defense, Box 465, File "100 Guided Missiles—Marriage Program," NA.

8. Chapman, *Atlas*, 57–9; Enclosure to letter, J. R. Dempsey, Manager, Convair Astronautics, to Edwin L. Weisl, Special Counsel, Preparedness Subcommittee, Armed Services Committee, US Senate, *Hearings before the Preparedness Investigation Subcommittee,* 2254.

9. Transcript, "Presentation of USAF Long Range Rocket Program by Dr. J. E. Lipp at the 30th Meeting of the Committee on Guided Missiles, RDB, Washington D.C., on 26 January 1951," in RG 156, Office of the Chief of Ordnance, Records Relating to the Army Guided Missiles Program, Box 12, File "GM 237/Atlas," NA.

10. Transcript, "Presentation of USAF Long-Range Rocket Program."

11. Beard, *Developing the ICBM*, 96, 132–3.

12. Krudener, *History of Ballistic Missiles Site Activation*, 17; Werrell, *Evolution of the Cruise Missile*, 97; Heppenheimer, "The Navaho Program."

13. Beard, *Developing the ICBM*, 96.

14. "ATLAS Strategic Rocket Project," May 7, 1952, in RG 156, Office of the Chief of Ordnance, Records Relating to the Army Guided Missiles Program, Box 12, File "GM 237/Atlas," NA; "(Restricted) Request for Approval of Popular Name for United States Air Force Guided Missile Project MX-1593," July 30, 1951, in RG 330, Office of the Secretary of Defense, Box 396, "237/GM," NA; Krudener, *History of Ballistic Missiles Site Activation*, 18–9; Chapman, *Atlas*, 62; Futrell, *Ideas, Concepts, Doctrine*, 487–8; Beard, *Developing the ICBM*, 133–4; Davies and Harris, *RAND's Role*, 45.

15. Gorn, *Harnessing the Genie*, 46–9; Collins, *Cold War Laboratory*, 173.

16. Gorn, *Harnessing the Genie*, 45–50, 59–62; Futrell, *Ideas, Concepts, Doctrine*, 276–8; Beard, *Developing the ICBM*, 107–21; Johnson, *The United States Air Force and the Culture of Innovation*, 36–9.

17. Rhodes provides one of the best accounts of the development of the thermonuclear bomb. See *Dark Sun*, 246–7, 462–72, 495–512. Other important works are Hansen, *US Nuclear Weapons*, 49–50; Herken, *Winning Weapon*; Kaplan, *Wizards of Armageddon*; Rhodes, *Arsenals of Folly*; idem, *Making of the Atomic Bomb*.

18. There are many accounts of this episode in Oppenheimer's life, including Rhodes, *Dark Sun*, 530–59, and Macrae, *John von Neumann*, 351–3. See also Bird and Sherwin, *American Prometheus*. Accounts of von Neumann's life can be found in Macrae, *John von Neumann*, and Dyson, *Turing's Cathedral*.

19. Rhodes, *Dark Sun*, 579–80. Teller continued to promote new and controversial weapons concepts over his long life. In the 1980s, Teller was one of the people most responsible for persuading President Ronald Reagan to embrace ballistic missile defense in the form of the Strategic Defense Initiative, also called Star Wars by its many critics.

20. Rear Adm. N. G. Lalor, Secretary, JCS, to Chairman, RDB, "Strategic Guidance to the Research and Development Board on Guided Missiles," February 2, 1951, plus Appendix A, "Operational Requirements for Guided Missiles," Appendix B, "Accelerated Guided Missiles Program, and Appendix C, Other Missile Projects," and Report by the Joint Strategic Plans Committee to the JCS on Strategic Guidance to the Research and Development Board on Guided Missiles, January 24, 1951, both in RG 218, Records of the Joint Chiefs of Staff, Box 108, File "JCS 334 Guided Missiles Comte (116-45) Sec 3," NA. During the Truman administration, the military planned around the "year of maximum peril," then assumed to be 1954. In April 1953, the Eisenhower administration replaced this policy with what it called a "long haul" planning policy for the armed forces. For more detail on these planning policies, see Glenn R. Snyder, "The 'New Look' of 1953," in Schilling et al., *Strategy, Politics and Defense Budgets*, 400–406.

21. US House of Representatives, *Hearings before the Select Committee on Astronautics and Space Exploration*, 1498–519; Hyland, *Call Me Pat*, 338. McMath is best known for his work in astronomy, which led to his appointment as director of what would become the McMath-Hulbert Solar Observatory in Michigan. The McMath-Pierce solar telescope at Kitt Peak National Observatory is named in his honor. For more on McMath, see Mohler and Dodson-Prince, *Robert Raynolds McMath*.

22. K. T. Keller, "Final Report of the Director of Guided Missiles," September 17, 1953, in Keller Papers, Harry S. Truman Presidential Library and Museum (HSTL).

23. Neufeld, *Ballistic Missiles*, 70–1; Chapman, *Atlas*, 63–4; Del Papa and Goldberg, *Strategic Air Command Missile Chronology*.

24. Col. R. L. Johnston, "Initial Presentation of Atlas Project Made at the 40th Meeting of the Committee on Guided Missiles," May 21–22, 1952, in RG 330, Office of the Secretary of Defense, Box 396, 42nd Meeting of GM Committee, File "237/GM," NA.

25. Johnston, "Initial Presentation of Atlas Project," May 21–22, 1952. Emphasis in original. The Air Research and Development Command had taken responsibility for missiles from the Air Materiel Commond. Johnston commented that the MX-774 had been canceled "due to lack of funds and the belief that the solution by other methods was closer at hand."

26. Committee on Guided Missiles, RDB, "Item 5: Presentation of ATLAS Long-Range Surface-to-Surface Missile Project," Agenda of 40th Meeting, May 21–22, 1952, with Col. B. K. Holloway to Chairman, Committee on Guided Missiles, "ATLAS Strategic Rocket Program," May 7, 1952, and Col. B. K. Holloway to Chairman, Committee on Guided Missiles, "ATLAS FY 1953 Program," May 28, 1952, in RG 156, Office of the Chief of Ordnance, Records Relating to the Army Guided Missiles Program, Box 12, File "GM 237/Atlas," NA.

27. Johnston, "Initial Presentation of Atlas Project," May 21–22, 1952. Neufeld, *Ballistic Missiles*, 71, 73; Edwin A. Speakman to Deputy Chief of Staff, USAF, "Conduct of ATLAS Missile Program," September 17, 1952, in RG 330, Office of the Secretary of Defense, Box 196, File 42nd Meeting of GM Committee, NA.

28. Lonnquest, "Face of Atlas," 32–5; Neufeld, *Ballistic Missiles*, 73–4; Beard, *Developing the ICBM*, 133–9.

29. Clark B. Millikan, "Report of the USAF Scientific Advisory Board's Ad Hoc Committee on Project Atlas," December 30, 1952, in RG 330, Office of the Secretary of Defense, Box 396, 42nd Meeting of GM Committee, File "237/GM," NA. The other members of the committee were: Hendrick W. Bode of Bell Labs; M. U. Clauser, who would later work at Space Technology Laboratories; Charles Stark Draper of the Massachusetts Institute of Technology; George B. Kistiakowsky of Harvard University and later a presidential science advisor; G. F. Metcalf of General Electric; Homer J. Stewart of Caltech; and Maurice J. Zucrow of Purdue University.

30. Millikan, "Report of the USAF Scientific Advisory Board's Ad Hoc Committee," December 30, 1952.

31. Lonnquest, "Face of Atlas," 35–8; Neufeld, *Ballistic Missiles*, 74–9.

32. Beard, *Developing the ICBM*, 5; MacKenzie, *Inventing Accuracy*, 102; Werrell, *Evolution of the Cruise Missile*, 104, 106; idem, *Death from the Heavens*, 249; Project RAND, *Preliminary Design of an Experimental World-Circling Spaceship*, 198; Powell-Willhite, *Voice of Dr. Wernher von Braun*, 18; Wernher von Braun, "Crossing the Last Frontier," *Collier's,* October 18, 1952, 27–73, reproduced in Logsdon, *Exploring the Unknown*, 188.

33. Gordin, *Red Cloud at Dawn*, 82.

34. Gordin, *Red Cloud at Dawn*, 80–3. Bulkeley discusses American intelligence on Soviet rocket and space programs in *Sputniks Crisis*, although many of his conclusions are outdated. See also Burrows, *Deep Black*; G. A. Tokaty, "Soviet Rocket Technology," in Emme, *History of Rocket Technology*, 271–84; Beard, *Developing the ICBM*, 163–4.

35. Beschloss, *Mayday*, 77–9; Sheehan, *Fiery Peace in a Cold War*, 215–7. The U-2 flights ended abruptly in May 1960 when a U-2 piloted by Francis Gary Powers was shot down by the Soviet military.

36. "Background Data on Questions Submitted in Enclosure A," attached to Karl F. Kellerman, Committee on Guided Missiles, to the Program Division, RDB, "Foreign Intelligence," undated but probably November 1947, in RG 156, Office of the Chief of Ordnance, Records Relating to the Army Guided Missiles Program, Box 12, File "GM 291/Foreign Intelligence," NA. Emphasis in original.

37. Maj. Gen. E. E. Partridge, Acting Deputy Chief of Staff, Operations to Secretary of the Air Staff, "Data for the President's Air Policy Commission Concerning Guided Missiles," Routing and Record Sheet, October 28, 1947, attached to Self, *History of the Development of Guided Missiles*.

38. Memorandum to Colonel Boatner and Captain Pihl, "Air Policy Commission," Memo No. 39, undated but probably October 1947, attached to Self, *History of the Development of Guided Missiles*.

39. Technical Evaluation Group, Committee on Guided Missiles, RDB, "The National Guided Missiles Program," May 20, 1949, in RG 218, Records of the Joint Chiefs of Staff, Box 107, File "JCS 334 Guided Missiles Comm (116-45) Sec 2," NA; Gordin, *Red Cloud at Dawn*, 257–9.

40. Central Intelligence Agency, Office of Scientific Intelligence, "Soviet Flame and Combustion Research and Its Relation to Jet Propulsion (Including Rocket Propulsion)," November 10, 1949, PSF, Intelligence, Box 258, Folder O.S.I./S.R, HSTL.

41. National Intelligence Estimates are contained in RG 363.5, Records of the Central Intelligence Agency, Textual Records (General), NA. "Soviet Capabilities and Intentions," NIE-3, November 11, 1950, is contained in Box 1, Folder 1. "Soviet Capabilities for a Military Attack on the United States before July 1952," SE-14, October 23, 1951, is in Box 1, Folder 20.

42. Draft, Fred A. Darwin to Chairman, RDB, "Intelligence Information Pertaining to Guided Missiles," December 20, 1950, in RG 156, Office of the Chief of Ordnance, Records Relating to the Army Guided Missiles Program, Box 12, File "GM 291/Foreign Intelligence," NA.

43. Neufeld, *Ballistic Missiles*, 71; Krudener, *History of Ballistic Missiles Site Activation*, 22; Sheehan, *Fiery Peace in a Cold War*, 217; Zaloga, *Target America*, 140–1. The intelligence sources weren't specified. When the Soviets began building the R-7 ICBM later in the decade, they turned to multichamber engines as a way to get around the problems of building large rocket engines.

44. I. D. Black, "Trip Report: Guided Missiles Intelligence Panel," August 11, 1952, in RG 330, Records of the Secretary of Defense, Box 394, File "123/Intelligence GM," NA. This presentation has been included in many historical treatments of ICBMs because it was mentioned in Schwiebert, *History of the U.S. Air Force Ballistic Missiles*, 58.

45. US Senate, *Hearings before the Preparedness Investigating Subcommittee*, 582.

CHAPTER 8: ICBMs Get the Go-Ahead

1. For an overview of the "New Look" and "massive retaliation," see Glenn H. Snyder, "The 'New Look' of 1953," in Schilling et al., *Strategy, Politics and Defense Budgets*, 379–524; Kaplan, *Wizards of Armageddon*, 174–84; and Carter, "Eisenhower versus the Generals." For more on Eisenhower's defense policy, see Bowie and Immerman, *Waging Peace*. Eisenhower's memoir of his first term in office is *The White House Years*.

2. Futrell, *Ideas, Concepts, Doctrine*, 423–4; Leighton, *Strategy, Money and the New Look*, 21–36; Zachary, *Endless Frontier*, 364–5.

3. Futrell, *Ideas, Concepts, Doctrine,* 423–4; Leighton, *Strategy, Money and the New Look,* 21–36; testimony of Roger M. Keyes, Deputy Secretary of Defense, June 17, 1953, US House of Representatives, *Reorganization Plan No. 6 of 1953*, 11; York and Greb, "Military Research and Development," 13–26.

4. Armacost, *Politics of Weapons Innovation*, 57; Neufeld, *Ballistic Missiles*, 95–9; Hughes, *Rescuing Prometheus*, 82–4; Sheehan, *Fiery Peace in a Cold War*, 195–200.

5. Sheehan, *Fiery Peace in a Cold War*, 178–200. Gardner warned of possible Soviet ballistic missiles in a March 1953 article in *Air Force* magazine. Lonnquest and Winkler, *To Defend and Deter*, 33–4; Lonnquest, "Face of Atlas," 60; Neufeld, *Ballistic Missiles*, 98. Interview of Gen. Bernard Schriever by Martin Collins, September 5, 1990, RAND History Project, National Air and Space Museum, Smithsonian Institution, Washington, DC.

6. Besides Von Neumann, Ramo, and Wooldridge, the committee's members included Charles C. Lauritsen, Clark B. Millikan, and Louis G. Dunn (a former director of the Jet Propulsion Laboratory) of Caltech; George B. Kistiakowsky of Harvard; Jerome B. Wiesner of MIT; Hendrik Bode of Bell Labs; Lawrence A. "Pat" Hyland of Bendix Aviation Corporation; and Allen E. Puckett of Hughes Aircraft. Kistiakowsky and Wiesner went on to become presidential science advisors. Lonnquest, "Face of Atlas," 89–95; Neufeld, *Ballistic Missiles*, 95–9; US House of Representatives, Subcommittee of the Committee on Government Operations, *Organization and Management of Missile Programs*, 9–13, 69–73.

7. Lonnquest, "Face of Atlas," 78–83.

8. Sheehan in *Fiery Peace in a Cold War* provides an excellent account of the Tea Pot Committee, including how the code name "Tea Pot" was selected to help conceal the committee's purpose (211).

9. Hyland, *Call Me Pat*, 336–43.

10. "The Tea Pot Committee Report," including correspondence, in Neufeld, *Ballistic Missiles*, Appendix 1, 249–65; Sheehan, *Fiery Peace in a Cold War*, 217–20. In his memoir, Ramo highlighted 1953 intelligence findings that the Soviets were well along in developing their own ICBM, but the evidence that will be discussed later does not support his account. Ramo did say that the ICBM presented major technical challenges, including those related to rocket engines, guidance, and reentry. Ramo, *Business of Science*, 78–89.

11. "Tea Pot Committee Report"; Sheehan, *Fiery Peace in a Cold War*, 214–20.

12. Augenstein, *Revised Development Program*; Kaplan, *Wizards of Armageddon*, 112–7; Augenstein interview by Collins and Tatarewicz.

13. Augenstein, *Revised Development Program*, 9.

14. Neufeld, *Ballistic Missiles*, 97, 104–10; Lonnquest, "Face of Atlas," 101–4.

15. Rhodes, *Dark Sun*, 541–3; Hansen, *US Nuclear Weapons*, 64–8; Sheehan, *Fiery Peace in a Cold War*, 216–7; Kaplan, *Wizards of Armageddon*, 112–7; Davies and Harris, *RAND's Role*, 46.

16. Gen. Putt testimony, May 18, 1956, US Senate, Subcommittee on the Air Force of the Committee on Armed Services, *Hearings*, 644.

17. Maj. Gen. Bernard Schriever, testimony, June 20, 1956, US Senate, Subcommittee on the Air Force of the Committee on Armed Services, *Hearings*, 1156; Gen. Bernard Schriever, testimony, February 21, 1958, US House of Representatives, Committee on Armed Services, *Investigation of National Defense Missiles*, 4852; Gen. Bernard Schriever, testimony, February 4, 1959, US House of Representatives, Subcommittee of the Committee on Government Operations, *Organization and Management of Missile Programs*, 10. Schriever's article in Gantz, *United States Air Force Report on the Ballistic Missile* also credits the "thermonuclear breakthrough" and the Tea Pot Committee with opening the door for ICBMs (27).

18. Swenson et al., *This New Ocean*, 59–61; T.A. Heppenheimer, *Facing the Heat Barrier*, 23–53.

19. Swenson et al., *This New Ocean*, 59–63; Augenstein, *Revised Development Program*, 21–31; Lonnquest and Winkler, *To Defend and Deter*, 32–3; John W. Finney, "Blunt-Nosed Concept in Ballistic Missile Hailed as Success," *New York Times,* May 18, 1957, 2. See Hughes, *Rescuing Prometheus*, 126–31, and Miller, *X-Planes*, 212–7, for discussions of warhead testing work after 1955.

20. Swenson et al., *This New Ocean*, includes an extensive discussion of the development of shapes and materials for ICBM warheads and especially early spacecraft (59–74), and so does Heppenheimer, *Facing the Heat Barrier.*

21. MacKenzie, *Inventing Accuracy*, 113–23.

22. "Soviet Capabilities and Probable Program in the Guided Missiles Field," NIE-11-5-57, March 12, 1957, Box 10, Folder 4, RG 363.5, Records of the Central Intelligence Agency, Textual Records (General), NA. This NIE superseded another NIE, dated October 5, 1954, which was not available, probably because it is still classified. See also Divine, *Sputnik Challenge*, 30–32, and Roman, *Eisenhower and the Missile Gap*, 30–62, for post-Sputnik US intelligence on Soviet ICBMs. Tyuratam is better known as Baikonur, the official but misleading name used by Soviet authorities to designate the launching facility. The R-7 designation for the missile was not known for many years after it came into use, and it was known in the West as the SS-6 Sapwood, a designation created by NATO.

23. Zaloga, *Target America*, 132–4, 143–5; idem, *Kremlin's Nuclear Sword*, 42–5; Siddiqi, *Challenge to Apollo*, 125–8; Chertok, *Rockets and People*, 2:231–2; Siddiqi, *Red Rockets' Glare*, 248–60, 274–8.

24. Siddiqi, *Red Rockets' Glare*, 244–8, 264–70; idem, *Challenge to Apollo*, 97–109. The first true Soviet thermonuclear bomb was exploded in November 1955.

25. Siddiqi, *Red Rockets' Glare*, 270–8; idem, *Challenge to Apollo,* 128–9; Zaloga, *Target America*, 134–41; idem, *Kremlin's Nuclear Sword*, 42–6; Chertok, *Rockets and People*, 2:275–6, 289–90; Holloway, *Stalin and the Bomb,* 294–319; Sakharov, *Memoirs*, 180–1.

26. Zaloga, *Kremlin's Nuclear Sword*, vi; Siddiqi, *Challenge to Apollo*, ix, x.

27. Beard, *Developing the ICBM*, 12, 218.

CHAPTER 9: Deploying ICBMs

1. Neufeld, *Ballistic Missiles*, 97, 104–10; Lonnquest, "Face of Atlas," 101–4; Tillman, *LeMay*, 130–2; Sheehan, *Fiery Peace in a Cold War*, 220–4. The committee was eventually renamed as the ICBM Scientific Advisory Committee.

2. Neufeld, *Ballistic Missiles*, 110–5; Sheehan, *Fiery Peace in a Cold War*, 253–60; Roland, *Military-Industrial Complex*, 26–7; Maj. Gen. Bernard A. Schriever, "The USAF Ballistic Missile Program," in Gantz, *United States Air Force Report on the Ballistic Missile*, 30. See also Hughes, *Rescuing Prometheus*, 69–139; Johnson, *Secret of Apollo*. A sharply critical view of Ramo-Wooldridge's role in Atlas is provided by Nieburg, *In the Name of Science*, 200–217.

3. Neufeld, *Ballistic Missiles*, 119–36; Hughes, *Rescuing Prometheus*, 102–9; Sheehan, *Fiery Peace in a Cold War*, 273–5, 315–8.

4. Neufeld, *Ballistic Missiles*, 137–76; Del Papa and Goldberg, *Strategic Air Command Missiles Chronology*; Sheehan, *Fiery Peace in a Cold War*, 343–61. At the same time, Army Ordnance was locked in a contest with the navy to launch America's first satellite into orbit. The army's Explorer 1 made it into orbit on January 31, 1958, before the navy's Vanguard. The air force focused on developing its missiles and stayed out of the satellite contest until the Atlas was proven later in 1958. The competition between Thor and Jupiter is covered in depth in Armacost, *Politics of Weapons Innovation*.

5. Neufeld, *Ballistic Missiles*, 137–41, 168–73; Watson, *Into the Missile Age*, 170–1; Chertok, *Rockets and People*, 2:397–8; Zaloga, *Target America*, 141–50.

6. Sheehan, *Fiery Peace in a Cold War*, 396–9; Watson, *Into the Missile Age*, 160–1. McDougall, *Heavens and the Earth*, 141–56, describes the US reaction to Sputnik.

7. Divine, *Sputnik Challenge*, 34–8, 77–9; Roman, *Eisenhower and the Missile Gap*, 30–3.

8. Congressman William G. Bray (R-Indiana), remarks at the luncheon meeting of the Indiana Republican Editorial Association, Indianapolis, March 26, 1960, Bryce Harlow Papers, Box 11, "Defense," Dwight D. Eisenhower Presidential Library; Mieczkowski, *Eisenhower's Sputnik Moment*, 140–1.

9. Neufeld, *Ballistic Missiles*, 168–76; Sheehan, *Fiery Peace in a Cold War,* 396–406; Watson, *Into the Missile Age*, 170–1; Del Papa and Goldberg, *Strategic Air Command Missiles Chronology*.

10. Zaloga, *Target America,* 150–60, 189–99; idem, *Kremlin's Nuclear Sword,* 47–57; Khrushchev, *Nikita Khrushchev and the Creation of a Superpower*, 278–89; Siddiqi, *Challenge to Apollo*, 212–9, 256–8; Sheehan, *Fiery Peace in a Cold War*, 403–9. See also McDougall, *Heavens and the Earth*, 237–62, and Mieczkowski, *Eisenhower's Sputnik Moment*, 19–20. Although Khrushchev claimed to have thought of the idea of missile silos himself, the concept had already been developed by the German creators of the V-2 in World War II.

11. Sheehan, *Fiery Peace in a Cold War*, 406–9; Neufeld, *Ballistic Missiles*, 176–9, 205–22; Del Papa and Goldberg, *Strategic Air Command Missiles Chronology*.

12. Kaplan, *Wizards of Armageddon*, 185–247.

13. Cloud, "Crossing the Olentangy River"; Warner, "From Tallahassee to Timbuktu"; idem, "Political Geodesy"; Day, "Mapping the Dark Side of the World," Parts I and II. See also Major Kenneth A. Smith, "The Ballistic Missile and Its Elusive Targets," in Gantz, *United States Air Force Report on the Ballistic Missile*, 261–70, for a 1958 view of missiles and geodesy. The branches of the military also used knowledge gained from satellites to conceive of and eventually deploy satellite-based navigation systems known today as GPS, or the Global Positioning System.

14. Sheehan, *Fiery Peace in a Cold War*, 409–20; Werrell, *Death from the Heavens*, 321n15; Tillman, *LeMay*, 130–2; Miles, "The Polaris," in Emme, *History of Rocket Technology*, 162; Zaloga, *Target America*, 203–4, 213, 233–42; Interview of Paul Blasingame by Martin Collins, November 14, 1990, RAND History Project, National Air and Space Museum, Smithsonian Institution, Washington, DC, 15.

15. Werrell, *Evolution of the Cruise Missile*, 96–101. Because submarines could be moved and hidden, some observers questioned whether there was any further need for bombers or ICBMs, since the submarines carried sufficient firepower to destroy the Soviet Union.

16. Sheehan, *Fiery Peace in a Cold War*, 403–9; Zaloga, *Target America*, 150–60. See also McDougall, *Heavens and the Earth*, 151–64, 325–35; Spires, *On Alert*, 56.

17. Zaloga, *Target America*, 213.

18. See Rosenberg, "Origins of Overkill," 57. Expanding on Rosenberg's point, nuclear historian Richard Rhodes suggested that the triad was nothing more "than an artifact of interservice rivalries." *Arsenals of Folly,* 92.

19. Office of Public Affairs, Department of Defense, "Final Atlas ICBM Squadron Becomes Operational in SAC," News Release, December 19, 1962; Walker and Powell, *Atlas*, 163.

20. Zaloga, *Kremlin's Nuclear Sword*, 99–119.

21. See FitzGerald, *Way Out There in the Blue*.

22. The $42 billion figure comes from an uninflated figure of $5.2 billion from an estimate that included deploying twelve squadrons of Atlas ICBMs that the USAF made in 1962 for a congressional committee, quoted in Lonnquest, "Face of Atlas," 244. The $47 billion figure is from Schwartz, *Atomic Audit*. The $130 billion figure is taken from an uninflated $17 billion figure from 1965 in Schwiebert, *History of the U.S. Air Force Ballistic Missiles*, 139. The $219 billion figure is based on costs for the programs listed in Schwartz, *Atomic Audit*, 149. In 1996, Minuteman III missiles remained deployed. Rhodes, *Dark Sun*, 116, puts the cost of the Manhattan Project at $2 billion, or roughly $27 billion today.

23. For more on deployment issues and problems, see Schlosser, *Command and Control*, and Heefner, *Missile Next Door*.

24. Roland, *Military-Industrial Complex*, 3–4.

25. See Friedberg, *In the Shadow of the Garrison State*. In a garrison state, every aspect of life would come under military control.

26. Roland, *Military-Industrial Complex*, 8.

27. Sheehan, *Fiery Peace in a Cold War*, xix, 450–5; Gaddis, *Long Peace*, 104–46, 195–214, 232–3.

28. Rhodes, *Arsenals of Folly*, 297–301. See also Kugler, "Terror without Deterrence"; Barnet, "Ideology of the National Security State."

29. Gaddis, *Long Peace*, 232–3.

CHAPTER 10: The Space Race

1. For a thorough treatment of America's reaction to Sputnik, see Divine, *Sputnik Challenge*. Killian is quoted on p. xv.

2. The dual-use nature of missiles was just the first of many such technologies in the US space program. See Roger Handberg, "Dual-Use as Unintended Policy Driver: The American Bubble," in Dick and Launius, *Societal Impact of Spaceflight*, 353–68.

3. Dwayne A. Day, "Cover Stories and Hidden Agendas: Early American Space and National Security Policy," in Launius et al., *Reconsidering Sputnik*, 161–74.

4. Siddiqi, *Red Rockets' Glare*, 308–43. A Jupiter-C was used to launch America's first satellite, *Explorer 1*, in 1958.

5. Michael J. Neufeld, "Orbiter, Overflight, and the First Satellite: New Light on the Vanguard Decision," in Launius et al., *Reconsidering Sputnik*, 237–8.

6. Siddiqi, *Red Rockets' Glare,* 349–61.

7. McDougall, *Heavens and the Earth*, 132. See McDougall's discussion of Sputnik's direct impact on the United States (141–56).

8. Divine, *Sputnik Challenge*, 31–4.

9. For a discussion of Kennedy's space policy compared to Eisenhower, see Mieczkowski, *Eisenhower's Sputnik Moment,* 273–7.

10. Neufeld, *Von Braun,* 333–47; Medaris and Gordon, *Countdown for Decision*, 48; Johnson, *Secret of Apollo*, 115–53.

11. Walker and Powell, *Atlas*, 223–79.

12. Logsdon, *John F. Kennedy and the Race to the Moon*, 218–9, 231–5. Neufeld, "Orbiter, Overflight, and the First Satellite," 250–1.

13. See Logsdon, *John F. Kennedy and the Race to the Moon*, 237–9.

14. See Roland, *Military-Industrial Complex,* for examples of military, corporate, and political support of US weapons programs. See also Evangelista, *Innovation and the Arms Race*, and Armacost, *Politics of Weapons Innovation*. For more on social forces in technological systems, see Hughes, "Evolution of Large Technological Systems," 51–82.

Historiographical Essay: The Atlas in History

1. Launius, "Historical Dimension of Space Exploration," 23–8. Once settled in the United States, the von Braun team was based at Huntsville, Alabama. The "Huntsville School" was first described by historian Rip Bulkeley in *Sputniks Crisis*, 204–8.

2. Beard's work relied heavily on two official air force historical studies: Self, *History of the Development of Guided Missiles*, and DeHaven, *Aerospace*. Unfortunately, most of the DeHaven study, including the portions relevant to the present book, remains classified. Beard had access to many documents on the condition that his notes be cleared by security personnel. Beard, *Developing the ICBM*, ix.

3. Beard, *Developing the ICBM*, 4. As mentioned, only six launch complexes were built for the R-7. By the end of 1962, 123 operational Atlas ICBMs were on station. Siddiqi, *Challenge to Apollo*, 213; Sheehan, *Fiery Peace in a Cold War*, 396–406.

4. Beard, *Developing the ICBM*, 8, 68–72, 124–8, 218; Perry, *Ballistic Missile Decisions*, 5.

5. Beard, *Developing the ICBM*, 218–21.

6. Beard, *Developing the ICBM*, 124–8, 140–4; Rhodes, *Dark Sun*, 461–72. John A. Alic states in "Origin and Nature of the 'Military-Industrial Complex'" that a lightweight tactical fission warhead similar in power to the the Hiroshima bomb had been created in 1950 and went into production in 1952.

7. Morison's essay was published as a chapter of his *Men, Machines and Modern Times* (see 35–40).

8. Perry, *Ballistic Missile Decisions*, 25–7; Beard, *Developing the ICBM*, 8, 229–35.

9. Morison, *Men, Machines and Modern Times*, 23–37. See Brown, *Flying Blind*, for a critical look at USAF strategic bombing aircraft.

10. Sheehan, *Fiery Peace in a Cold War*, 412–5. See chap. 9 for a discussion of Minuteman's advances over Atlas and Titan.

11. Robert L. Perry, "The Atlas, Thor, Titan and Minuteman," in Emme, *History of Rocket Technology*, 142–3. The article was originally published in *Technology and Culture* 4 (1963): 466–77.

12. Perry, "Atlas, Thor, Titan and Minuteman."

13. Perry, "Atlas, Thor, Titan and Minuteman."

14. Perry, *Ballistic Missile Decisions*, 5–11.

15. Hughes, *Rescuing Prometheus*, 77.

16. Hughes, *Rescuing Prometheus*, 80.

17. Hughes, *Rescuing Prometheus*, 77.

18. Hughes, *Rescuing Prometheus*, 76–84; idem, *American Genesis*, 459–61.

19. Hughes, *Rescuing Prometheus*, 76–9. Hughes also provided a good summary of Schriever's and Simon Ramo's work in advancing systems engineering and in making Atlas and Titan a reality (73–139).

20. See Borowski, *Hollow Threat*.

21. Beard, *Developing the ICBM*, 124–8; McDougall, *Heavens and the Earth*, 97–107; Bulkeley, *Sputniks Crisis*, 60–86; Builder, *Icarus Syndrome*, 155–78; Hughes, *Rescuing Prometheus*, 76–9.

22. McDougall, *Heavens and the Earth*, 3–6, 81–107, 480n28.

23. Swenson et al., *This New Ocean*, 23–6.

24. Swenson et al., *This New Ocean*, 18–31, 59–69.

25. Beard, *Developing the ICBM*, 153–78; Lonnquest, "Face of Atlas," 65–99; Neufeld, *Ballistic Missiles*, 95–9; Futrell, *Ideas, Concepts, Doctrine*, 488–91; Johnson, *United States Air Force and the Culture of Innovation*, 60–3. Swenson et al., *This New Ocean*, 23–6, had also credited the thermonuclear breakthrough with advancing Atlas.

26. Neufeld, *Ballistic Missiles*, 1–107.

27. Futrell, *Ideas, Concepts, Doctrine*, 488–91.

28. Lonnquest, "Face of Atlas," 1–6, 23–4, 40.

29. Bulkely, *Sputniks Crisis*, 11, 12, 38–44, 49, 61–78.

30. MacKenzie, *Inventing Accuracy*, 98–115.

31. Johnson, *Secret of Apollo*, 32–3.

32. Chapman, *Atlas*, 25–75.

33. Sheehan, *Fiery Peace in a Cold War*, 214.

34. Sheehan, *Fiery Peace in a Cold War*, 211–24, 223, 414–5.

35. See von Braun and Ordway, *History of Rocketry and Space Travel*, and Ley, *Rockets, Missiles, and Men in Space*.

36. Braun and Ordway, *History of Rocketry and Space Travel*, 251–4.

37. Roland, *Military-Industrial Complex*, 8.

38. Bainbridge, *Spaceflight Revolution*, 4–8. The spaceflight movement of the 1920s is examined in Winter, *Prelude to the Space Age*.

39. McDougall, *Heavens and the Earth*.

40. Launius, "Historical Dimension of Space Exploration."

41. McCurdy, *Space and the American Imagination*, 53–82, 139–61.

42. McDougall, *Heavens and the Earth*, 6; Walter A. McDougall, "Introduction: Was Sputnik Really a Saltation?," in Launius et al., *Reconsidering Sputnik*, xviii.

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